PERIODICA POLYTECHNICA

ELECTRICAL ENGINEERING — ELEKTROTECHNIK

VOL. 4 * No. 1 * 1960

POLYTECHNICAL UNIVERSITY
TECHNISCHE UNIVERSITÄT
BUDAPEST
HUNGARY—UNGARN

PERIODICA POLYTECHNICA

Contributions to international technical sciences published by the Polytechnical University, Budapest (Hungary)

Originalbeiträge zur internationalen technischen Wissenschaft, veröffentlicht von der Technischen Universität, Budapest (Ungarn)

PERIODICA POLYTECHNICA

includes the following series

Engineering
Electrical Engineering including Applied Physics
Chemical Engineering

enthält folgende Serien

Maschinen- und Bauwesen
Elektrotechnik und angewandte Physik
Chemisches Ingenieurwesen

The issues of each series appear at quarterly intervals

Einzelnummern der genannten Serien erscheinen vierteljährlich

---

CHAIRMAN OF THE EDITORIAL BOARD — HAUPTSCHRIFTLEITER

Z. CSŰRÖS

EDITORIAL BOARD — SCHRIFTLEITUNG

N. BÁRÁNY, O. BENEDIKT, S. BORBÉLY, T. ELEK, L. ERDEY, J. GRUBER, I. KOVÁCS, L. KOZMA, G. SCHAY, K. TETTAMANTI

EXECUTIVE EDITOR — SCHRIFTLEITER

J. KLÁR

The rate of subscription to a series is $ 4,00 a year. For subscription or exchange copies please write to

Jahresabonnement pro Serie: $ 4,00. Bestellungen und Anträge für Tauschverbindungen sind zu richten an:

PERIODICA POLYTECHNICA

BUDAPEST 62, POB 440

MICROMETER ADJUSTMENT OF MIRRORS AND PRISMS

By

N. Bárány

Institute for Instrumental Design and Precision Mechanics,
Polytechnical University, Budapest

(Received November 24, 1959)

As far as the dimensioning of the reflecting surfaces is concerned, distinction must be made between prisms and mirrors, on account of the differences between refraction and reflection, irrespectively of the fact that, from the point of view of physics, refraction is but a special case of reflection. For an incident pencil of rays, parallel to the optical axis, as represented in Fig. 1, the length x of the reflecting faces of mirrors and prisms are equal. The situation is, however, different for parallel pencils constructing an angle with the optical axis (Fig. 2). The incident and emerging pencils are refracted

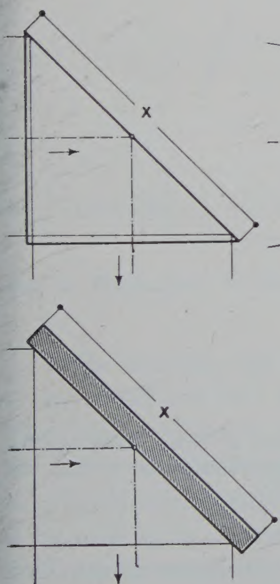


Fig. 1. The effective (free) reflecting face of prisms and mirrors has equal dimensions for pencils of rays entering parallel with the optical axis

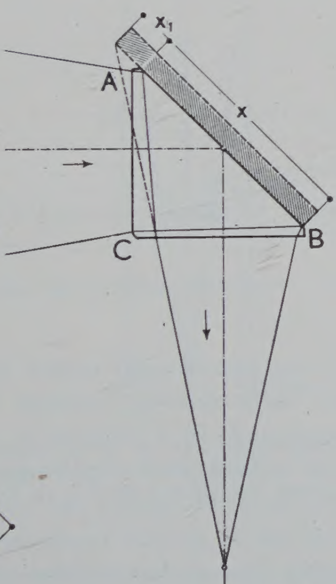


Fig. 2. The path of a pencil making an angle with the optical axis, in a prism, and if prism is replaced by a mirror

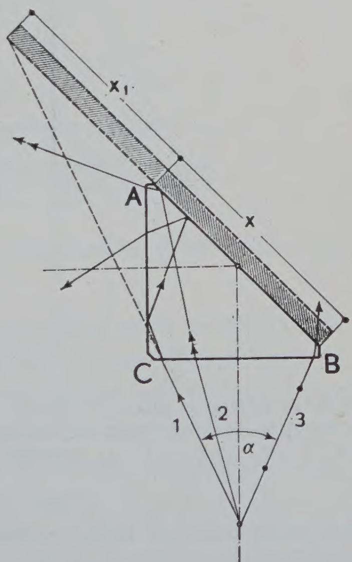


Fig. 3. Partial and total reflection as well as refraction of a wide-angle pencil in a prism. The mirror substituted for the prism has to be increased so as to be covered by marginal rays

at the faces AC and BC, respectively, cutting a useful surface x as reflecting portion from the face AB. Let us now substitute a mirror for the face AB. The pencil will reach the mirror unrefracted, but in this case, supposing an

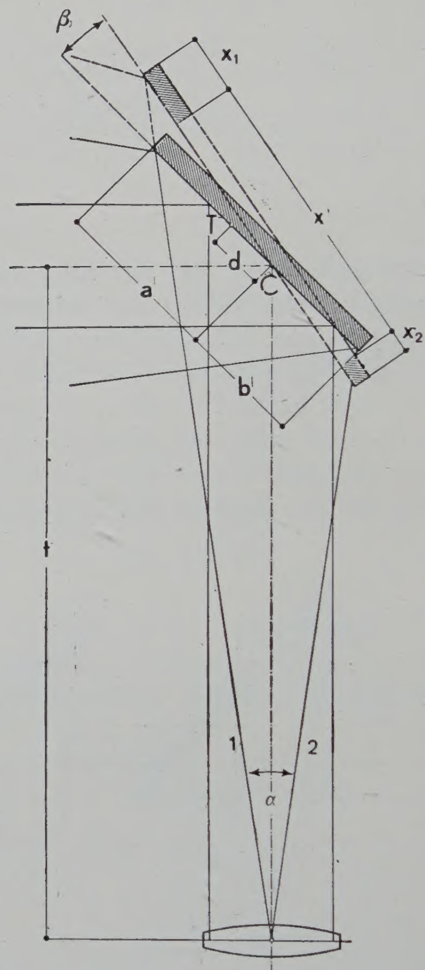


Fig. 4. Effect of mirror rotation. Mirror faces have to be increased in either direction by tilting, because of the marginal rays. In order to reduce the screening due to the mirror, the rotation centre was shifted from C to T

inverted path of rays, a reflecting face x_1 larger than the prism is required for receiving a pencil of full opening. Yet, the advantages inherent in refraction also involve certain disadvantages for wide-angle pencils (Fig. 3). The rays of a pencil emerging at angle α are refracted in the prism upon incidence. Before ray *1* should reach face AB, it is totally reflected on face AC so that it does not take part in image formation, and may entail inconvenient reflec-

tions which one may find impossible to eliminate. The ray *3* reaches face AB at an angle smaller than the boundary angle of the reflection, so that it is not only reflected but also refracted. In order to remove the resulting inconvenient reflections, the prism has to be replaced by a mirror x_1 which is larger than the length x of the prism.

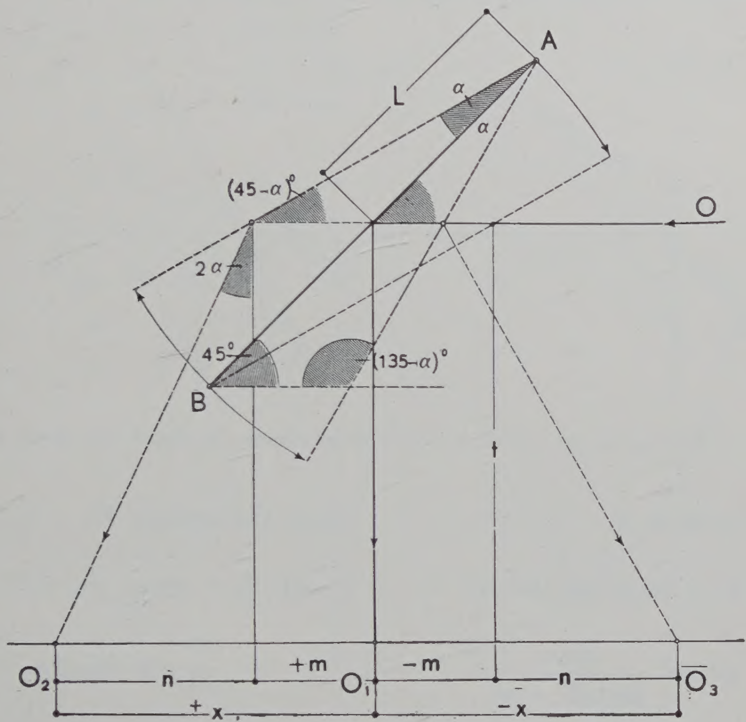


Fig. 5. Phenomena arising upon tilting the mirror, and displacement of the image point

On rotating the mirror (Fig. 4) the pencil travelling with inverted path of rays will cut out unequal portions from the face of the mirror [$a \neq b$]. The larger the angle of rotation β is, the longer the mirror has to be, so that the ray l may reach the edge of the mirror. A similar phenomenon is encountered at the other end of the mirror. Thus, one has to enlarge the original length x by adding x_1 at the upper and x_2 at the lower edge.

In the case of precision instruments the tilting of the mirror has to be computed taking the direction of the ray into consideration, that is, whether the ray travels from the image space to the object space, or vice versa (Fig. 5). The only difference between the two cases lies in the mirror being swung about either A or B, as rotation centres. For the sake of simplicity, only the axial ray has been represented. Let us suppose that the ray travelling from

the object point O is reflected as O_1, and the mirror is tilted through a 45° angle. If the mirror is swung vertically from the basis position through an angle α, the reflected ray will arrive to O_2, and, on an opposite rotation, to O_3. Let us denote displacement of the incident ray by $(+m)$ and $(-m)$, respectively, then the displacements observed at distance t will consist of two parts: a constant (n) and a variable part composed of the two (m)-s.

According to Fig. 5:

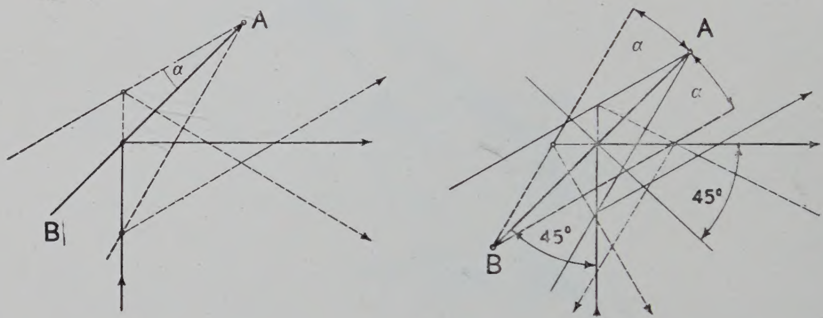


Fig. 6. Shifting of the ray for a mirror tilted about the upper and lower axis

From the scalene I:

$$m : \mathrm{L} = \sin \alpha : \sin\ (45°\text{-}\alpha]$$

$$m = L \frac{\sin \alpha}{\sin [45° - \alpha]}$$

From the scalene II:

$$[-m] : \mathrm{L} = \sin \alpha : \sin\ [135°\text{-}\alpha]$$

$$n = t \cdot \tan 2\,\alpha$$

$$[-x] = L \frac{\sin \alpha}{[\sin 135° - \alpha]} + t \cdot \tan 2\alpha$$

The displacement is $m + n = x$

$$x = L \frac{\sin \alpha}{\sin [45° - \alpha]} + t \cdot \tan 2\alpha$$

In other words, for a ray travelling in the optical axis, the two cases above referred to differ only in that the same axis of rotation is employed for rays of either direction, when tilting the mirror upwards or downwards from the basic position (Fig. 6). The derivation gives the following conclusions:

1. The image displacements are not equal: $x \neq (-x)$

2. The direction of the displacements is not similar: x being positive and $(-x)$ negative.

3. The reason for the difference in the image displacement is: $(-m) \neq \neq (+m)$.

Thus, we can see from the foregoing that the two axes of rotation represent opposite hand views.

Example: $\alpha_{\max} = 22°30'$
$L = 60$ mm
$t = 100$ mm
$x = 124.6$ mm and
$(-x) = 160$ mm.

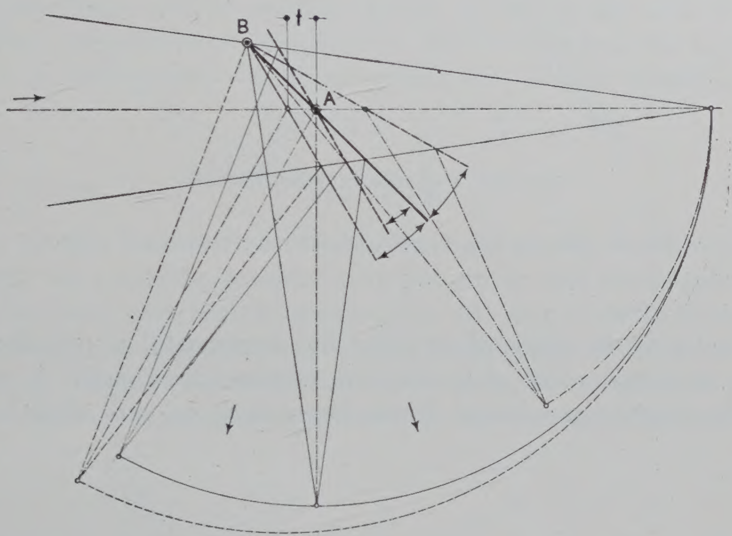


Fig. 7. Displacement of a pencil coming from infinity and made convergent by means of a lens, upon swinging the mirror about the rotation centre B

In Fig. 7 the axial pencil is directed by lens *l* convergently on to mirror *2*. The mirror is swung about point *B*, and not about the axial point *A*. The following conclusions may be established:

1. Swinging the mirror about axis *A* is more advantageous than about axis *B*, for in the case of equally small angles α it causes no stopping out of rays, but

2. this advantage is offset by the large amount of image displacement encountered.

Fig. 8 shows an arrangement in which the mirror is swung about axis *B*, placed rather low, hence, the motion is kinematically opposed to the previous one. We may thus make the statements that

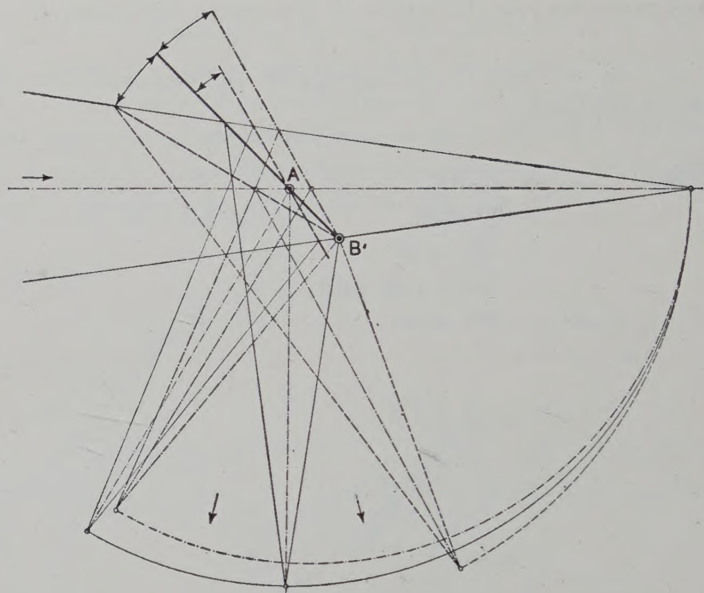


Fig. 8. Same as Fig. 7, with the mirror swung about axis *A*

1. swinging the mirror about point *B* is detrimental, as it leads to heavier screening or stopping out, than does the motion about point *A*.

2. In certain cases image displacement may be very slight.

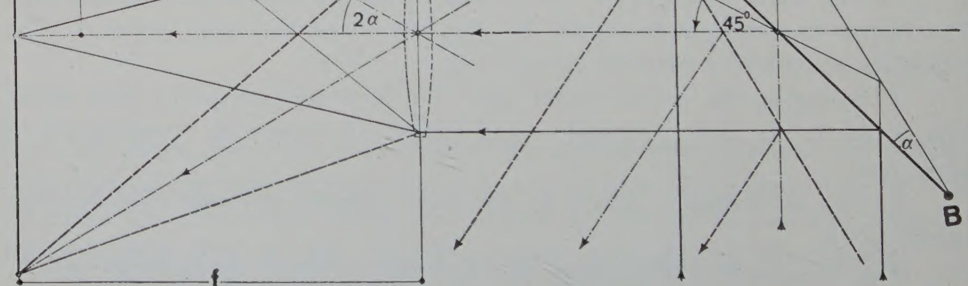


Fig. 9. For a pencil from infinity, the position of the image plane is independent of the position of the centre

If a parallel pencil reaches the mirror, as represented in Fig. 9, the position of the image plane is independing from the position of the rotation centre, since $\tan 2\,\alpha = x : f$. Image displacement is therefore: $f \cdot \tan\, 2\,\alpha$.

The foregoing derivations are true on the assumption that a front-coated mirror is used, but it is equally possible to employ a back-coated mirror which, naturally, has to consist of a plane-parallel glass plate. However, such mirrors can only be used when the path of rays is parallel, as pencils arriving from object points nearer than infinity are not collected by the lens in one image point. In addition, one has to consider the astigmatism due to oblique rays.

Reverting to Fig. 4, the inevitable screening of the rays, due to mirror rotation, may be lessened if the mirror is swung about axis T which is shifted towards the longer mirror portion cut out by the pencil, instead of being swung about the axial point. The distance d of the axis from the optical centre C is $a : 3$, a ratio which was found satisfactory for all practical purposes.

Micrometer control of mirrors

Let us now establish the correlation between the displacement of the micrometer screw serving as adjustor to the mirror, and the angular displacement of the lever carrying the mirror (Fig. 10). Let us suppose that lever *2* having a length L of plane mirror *3* rotating about point C is shifted, each revolution of the screw *1*, by uniform distances m. Since the angular displacement α of the mirror is not proportional to the shifting of the leading screw,

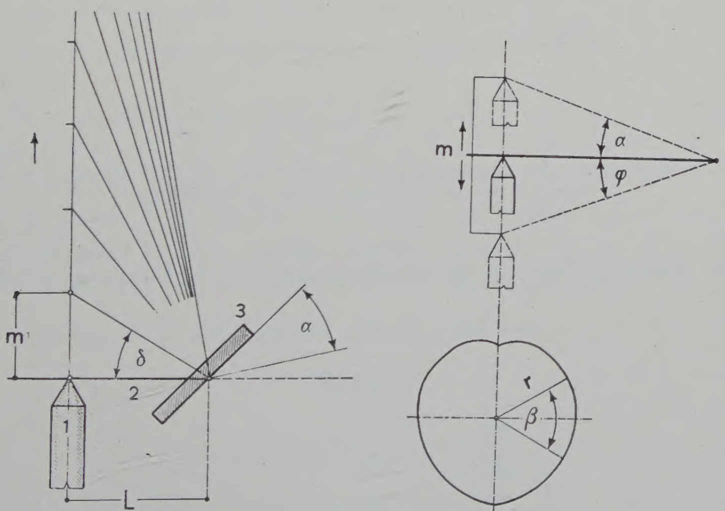


Fig. 10. Phenomena arising in connection with a mirror rotated by a micrometer leading screw, with the aid of a push rod

the drum cannot have linear scale divisions. It is therefore necessary to insert a means apt for ensuring linear readings, such as a cam disc, for displacing the leading screw. For the purpose of making the derivation of the curve of the disc's mantle, let δ represent the angular displacement of the disc, a the uniform angular displacement of the mirror, and L the length of the lever

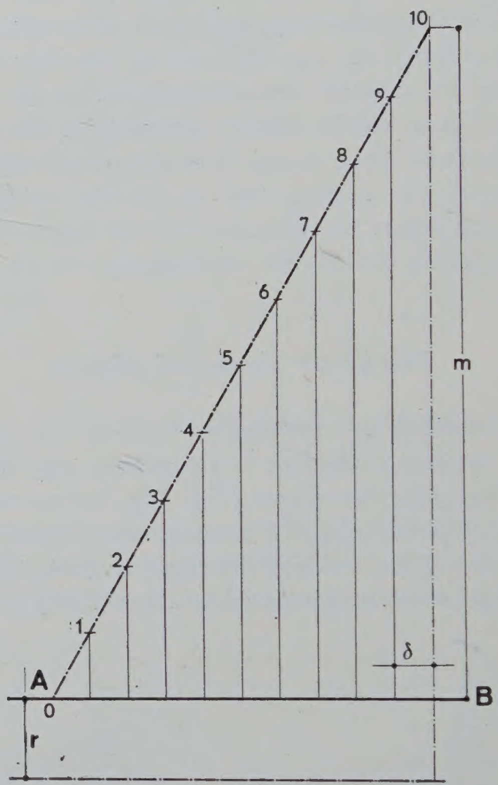


Fig. 11. Auxiliary diagram for the graphical construction of the curve of a control disc inserted to secure linear drum graduations

rotating the mirror. Then, in accordance with the indications of the figure:

$$m \cdot \tan \alpha + m \cdot \tan \varphi = r$$

$$r = r[\beta]$$

$$\frac{d\alpha}{d\beta} = c \qquad c \leq \beta \leq \pi$$

$$\alpha = c\,\beta + c'$$

$$r = m\,[\tan\,(c\,\beta + c') + \tan \varphi]$$

Computation of the constant member:

$$\text{at } \beta = 0 \quad r = 0$$

$$0 = m\,[\tan c' + \tan \varphi]$$

$$\tan c' = -\tan \varphi$$

$$r = m\,[\tan (c\,\beta - \varphi) + \tan \varphi]$$

$$\text{at } \beta = \pi \quad r = 2\,m \cdot \tan \varphi$$

$$2\,m \cdot \tan \varphi = [\tan (cr - \varphi) + \tan \varphi]$$

$$\tan \varphi = \tan\,[c\,\pi - \varphi]$$

$$\varphi + y\,\pi = c\,\pi - \varphi$$

$$c = \frac{2\,\varphi}{\pi} + y$$

at $y = 0$:

$$r = m\left[\tan\left(\frac{2\,\varphi}{\pi}\,\beta - \varphi\right) + \tan \varphi\right]$$

where β and φ are expressed in radians.

The formula reveals that the curve is not cardioid, because with B as the origin of the system of coordinates, and BC representing the direction of the axis x,

$$[y^2 + x^2 - 2\,rx]^2 = 4\,r^2\,[x^2 + y^2]$$

or, with γ and ε expressed in polar coordinates:

$$\gamma = 2\,r\,[1 + \cos \varepsilon]$$

For the graphical construction of the curve of the controlling disc, one can proceed as follows, as is illustrated in Fig. 11: Computing the values of r (multiplied by any arbitrary factor), parallel lines are traced by means of the normal at point B of the line AB across uniformly spaced points, corresponding in number to the angular displacements β of the disc. The values listed in the table below are transferred to these parallels.

A mirror rotation of $+10° =$	17.63
	15.83
	14.05
	12.27
	10.51
	8.74
	6.99
	5.24

3.49
1.74
0.00
1.74
3.49
.
.

mirror rotation of $-10° = 17{,}63$

The zero point corresponds to a 45° angle included between the mirror and the incident ray. The positive and negative values of the table being equal, the graphical construction will present a symmetrical formation.

The curve is obtained by first tracing a circle of an arbitrary radius r (Fig. 12). Then, optionally chosen but equal angles β are traced, starting from the centre 0 of the circle. In the example illustrated in the figure, β is $= 18°$. Then the distances m obtained according to Fig. 11 are transferred to the shanks of the angles. A leading screw engaging the periphery of a cardioid disc, so shaped, will secure uniform angular displacement of the mirror, hence permits to provide the disc with equidistant angular graduations. However, solutions of this type permit the utilization of only part of the disc's periphery. To avoid this, the curve has been extended to cover 328°, as represented in Fig. 13. In the basic position of the leading screw its pointed end engages the curve at A. A_1 is the terminal of the curve.

The above-described controlling cam disc secures uniform vertical graduations only in the case of a pointed leading screw engaging the lever *2* of length L at A. If the screw is vertically displaced by m, the length of the lever changes to L_2. As in practice the leading screw's end cannot be given a pointed shape, it is generally either rounded off, or a roller is pivoted in its forked end, preferably by means of ball bearings. Such an arrangement, however, modifies the manner of control. Let us suppose that in the basic position the pointed end of the leading screw engages the lever of the mirror at A, and the mirror constructs a 45° angle with the horizontally travelling radiation. Let us now replace the pointed end by a roller of radius r. If the roller is vertically displaced by m, the lever will engage point A_3 of the roller mantle, instead of A_1. The mirror will therefore be rotated to such an extent as if the pointed end had been displaced by a length y from A_1 to A_2. Thus, the roller control gives rise to an angular error δ, the size of which depends on radius r of the roller, and length L of the lever. This error can only be removed by an appropriate modification of the shape of the cam. From the triangle CA_2A_3:

$$r = \tan \alpha = x$$

$$y + r = \sqrt{r^2 + x^2} = \sqrt{r^2 + r^2 \cdot \tan^2 \alpha} - r$$

If r is 3 mm and $\alpha = 10°$, y will be 0.046, or 0.05 mm.

The value y associated with α has to be deduced from the scale length corresponding to each angular value.

The angular error δ is

$$\delta = \arctan \frac{m - r}{L} + \arcsin \frac{r}{\sqrt{(m - r)^2 + L^2}} - \arctan \frac{m}{L}$$

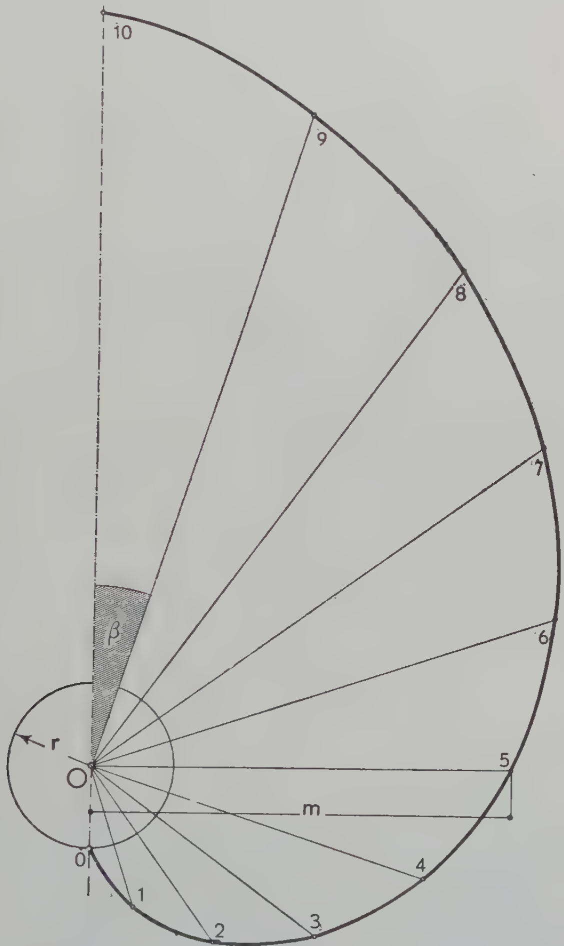


Fig 12. Graphical construction of the curve of the control disc

Plotting the values on a system of polar co-ordinates, the periphery of the cam disc can be graphically constructed.

Whatever the shape of the cam disc is, it will only operate precisely, that is, supply exact measurements, if its periphery is machined with high

precision. Accordingly, the manufacture of such discs, particularly if they are small and have to be produced in series, is rather expensive and cumbersome. It has, therefore, been suggested to eliminate the use of such discs by employing a parallel gear drive as represented in Fig. 15. Vertical adjustment is effected by means of a gear-driven rod system, and connected with a gear segment.

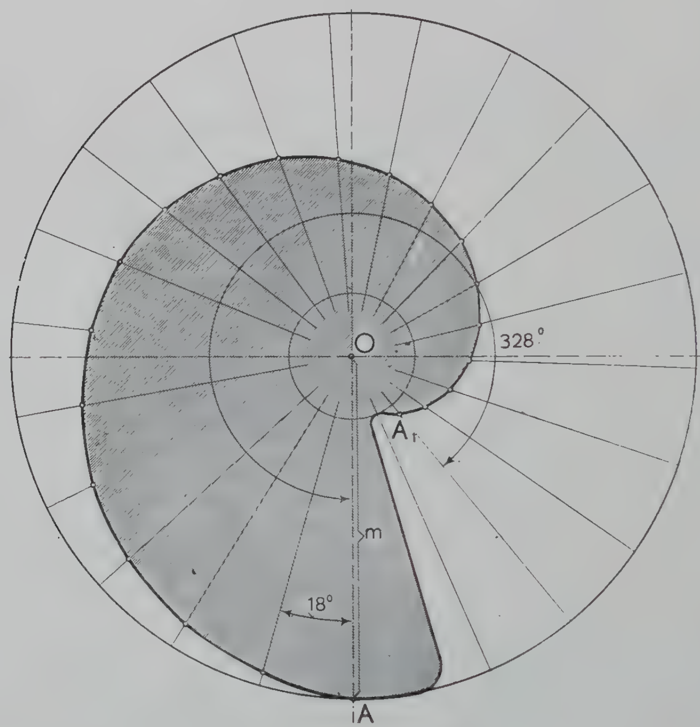


Fig. 13. Shape of the extended curve

The gear segment 13 is rotated by a wheel 21 over a worm drive 17 and a shaft 14 through a bevel gear transmission 15. With the insertion of a gear 12, the gear segment 13 rotates a drum 11 provided with suitable graduations. The shaft 14 of the wheel 21 rotates the drum 11 in such a manner that each revolution corresponds to one graduation. On the threaded part 16 of the shaft 14 the nut 19, secured against rotation, is displaced, and its nose butts against the fixed stop 18 at the end of its path. The delicate gear transmission of the reading device is protected in this way. A pivot 9 of the forked end of a lever 10 of the double-armed, lever-shaped gear segment 13 actuates a rod 8, whose upper two-piece end portion 5 serves to rotate the mirror 1 by means of lever 3 about shaft 2. Backlash is eliminated by the aid of spring 7, attached to lever 3. Exact adjustment of the rod length, that is, of the mirror position, is effected by sleeve nut 6.

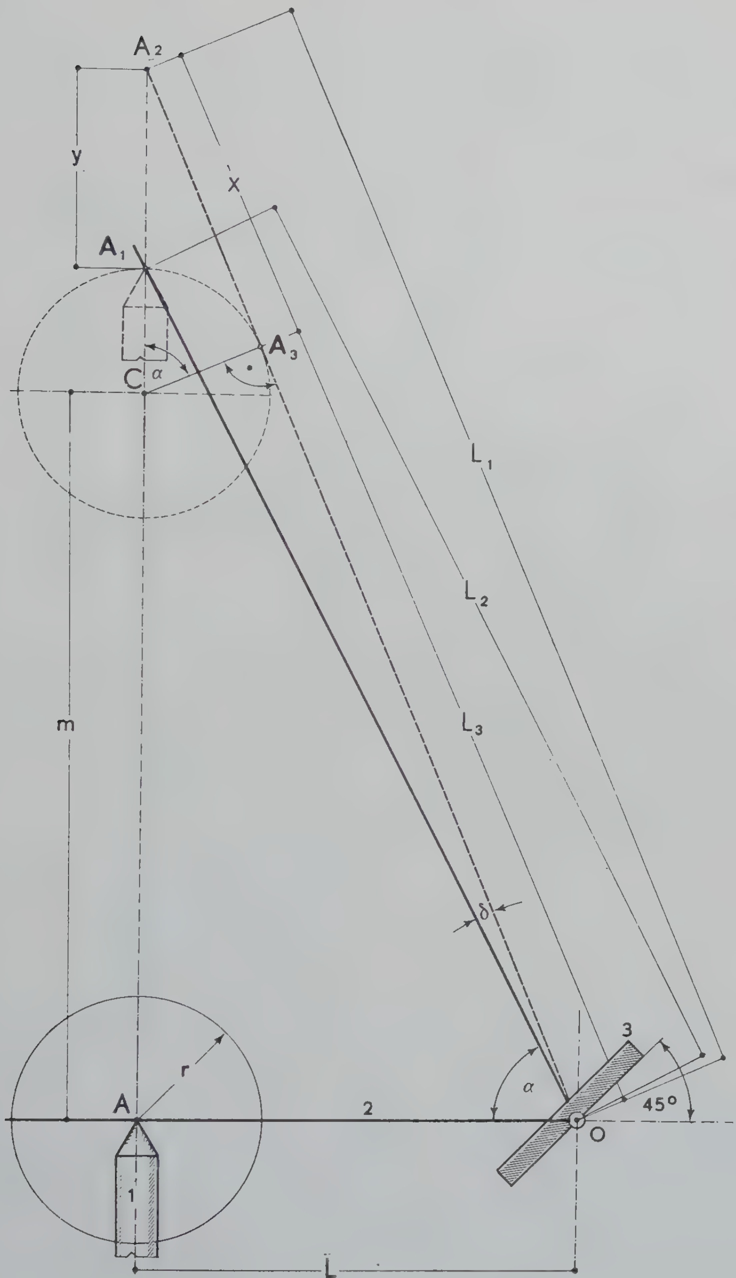


Fig. 14. **Operating principle of pointed and roller-ended micrometer leading screws**

When the sighting of object points situated at different altitudes, such as indoor reading of instrument graduations is intended, instead of angle measurements, one can resort to an extremely simple and inexpensive adjusting arrangement (Fig. 16), which for this purpose can readily replace the above-described costly equipment.

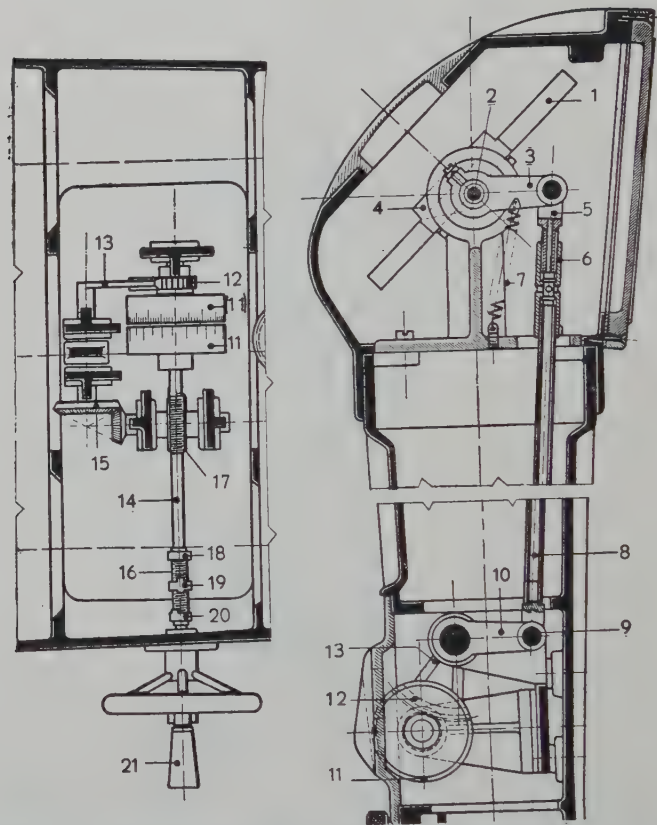


Fig. 15. Mirror shifting by parallel geare drive. The drum bears linear graduations

Head prism 1 rotates in ball bearings. A thin, twisted steel wire 2 connects the external mantle of the prism mounted to theadjusting equipment 3. In addition to the said role, this latter also serves to limit the rotation of the prism, as was described in connection with Fig. 15.

If the lever engages the end of the leading screw directly, this end part is usually rounded off with a certain radius (Fig. 17). In this case, however, the lever swinging about the point 0 rolls along the arc and engages the spherical surface of radius r at C_2. Peak C of the leading screw on the other hand is shifted to position C_1, thus giving rise to an error h. Accordingly, the nominal

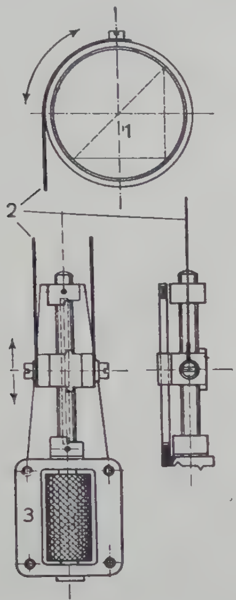


Fig. 16. Prism shifting by a simple wire control arrangement

drum reading will not correspond to the axial displacement of the leading screw The derivation of the error yields

$$h = \frac{r[k^2 - ry + y^2 + k\sqrt{k^2 - 2ry + y^2}]}{k^2 + [r - y]^2}$$

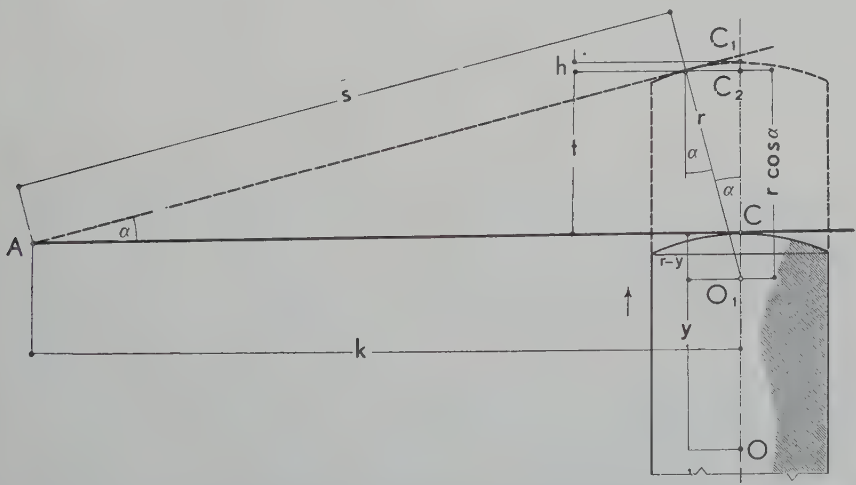


Fig. 17. Phenomena arising upon lever control, with the leading screw rounded off at a certain radius

In an equation of the second degree, a radial of positive sign has a meaning only if the result is positive. To ascertain this, practice has proven k to be smaller than r, which in turn is smaller than y. Accordingly, one can introduce appropriate neglections, as a result of which the error is

$$h = \frac{ry^2}{2\,k^2}$$

For practical purposes this means that the shorter r is, the smaller the axial displacement of the screw is and the longer the lever is, the smaller will the error be.

Summary

The paper is concerned with micrometer rotating arrangements for mirrors and prisms incorporated into instruments employed for angle measurement, with due regard to the optical, kinematical and precision mechanical correlations. The wire control arrangements devised and put into practice by the author at the Institute, of which he is the leader, proved to be of good use during a period of considerable length. The paper further specifies the limiting device which when locked in time will protect the measuring equipment against injuries. Finally, the paper describes the effect of pointed, rounded and roller-type leading screws.

Prof. N. BÁRÁNY, 17, Gombocz Zoltán utca, Budapest XI, Hungary.

A MICROWAVE METHOD OF MEASURING SURFACE ROUGHNESS

By

G. Almássy

Institute of Telecommunication, Polytechnical University, Budapest

(Received September 30, 1959)

1. Introduction

The electrical characteristics of microwave equipments, such as cavity resonators, transmission lines, depend a great deal on the characteristics of the walls which embody them. The currents flowing in the walls having finite conductance cause loss, the amount of which depends on the conductivity of the metal the walls are made of, and on their surface roughness.

The skin-depth of the materials used in microwave technique is very small (for example on 3000 MC/s the skin-depth in silver is 1.2 μ). The microwave loss is, therefore, determined by the uppermost layers of the walls, their thickness being a few microns at the most.

In practice the theoretical calculations assuming ideal smooth surface and homogeneous medium give somewhat lower losses, than those measured. The difference might have two reasons; first: the conductivity of the metal differs from the assumed value, second: the surface of the metal is rough. It might be theoretically proved that the specific resistance of metals increases, if the skin-depth is smaller than the so-called free path made by an electron in the metal between two collisions; or to put it in other words, if the time period of the microwave oscillation is in the same order as the time spent between two collisions of the electrons.

At normal ambient temperatures these phenomena become effective only on wavelengths of a few tenths of millimetres. More important is the fact that the specific conductivity of the test piece might differ a great deal from the ideal value assumed. There are several references in literature underlining the necessitiy of measuring the D. C. conductivity of the material under test, before the microwave measurements.

With this method, however, only the average specific conductivity of the tested material can be determined. The structure of the materials in practice is inhomogeneous, and besides this, the technological processes cause local changes in the conductivity, too. These latter, especially machining, are effective to those outer layers, in which the microwave currents flow. The surface

roughness of the wall might cause a considerable increase of loss, if the value of the unevenness is comparable with the skin-depth. According to data in the literature [1], 60% increase of loss results if the scratches on the surface are perpendicular to the direction of current flow. A much smaller increase in loss results if the scratches lie parallel to the wall currents.

From these it is apparent that losses depending on the qualities of the wall can only be determined experimentally.

To find the best technological method, all the different processes must be checked by a series of experimental measurements. It would be too expensive and in many cases the checking itself might be extremely difficult to achieve, if the technological tests were done on microwave apparatus, which are very expensive and exceedingly difficult to make.

The measuring method discussed above, which can be applied for checking the series of technological experiments, makes use of cylindrical test piece, one, which is easily made. The aim of the measurement is to determine the surface roughness due to microwave losses.

In order to select the effects on microwave losses of the specific resistance and the surface roughness of the metal used, the measurements must be made on two essentially different frequencies, and the ratios of the effective specific resistances measured on microwaves and on ultra-shortwaves, resp., will correspond to the microwave surface roughness.

The first measurement is made on a frequency on which the unevenness of the surface is negligible in comparison to the skin-depth. (According to available data in literature, a surface roughness of $^1/_4$-th the skin-depth causes only 4% increase of loss at the most.)

The specific resistance measurement was made on a frequency a 100 times less than the microwave band, so that the surface roughness was negligible in respect to the skin-depth in all the practically important cases.

During these measurements the skin-depth was in the order of .01 mm, so it was possible to determine the increase of specific resistance due to the changes of metal structure caused by the different technological processes. When special precautions are used, this method is also suitable for examining electro-plated layers. The specific resistance measured by microwaves was counted from the Q factor of a resonant cavity made specially for this purpose.

2. Measuring methods

2.1. Measurement of specific resistance on very high frequencies

The measurements were made on simple cylindrical test pieces, the dimensions of which were chosen according to the microwave band used. (This method is suitable for testing non-magnetic materials only.)

The cylindrical test piece was wound around the middle by a considerably shorter coil. The gap between the test piece and the coil is filled in by a low loss dielectric (*e. g.* polystyrene), as shown on Fig. 1. Suitable bumpers secured the same positions of both test piece and coil at all measurements. The higher the Q factor of the empty coil is, the greater is the accuracy and efficiency of the measurement. If test pieces with the same dimensions but of different materials are placed into the coil in the same position, the Q factors, measured

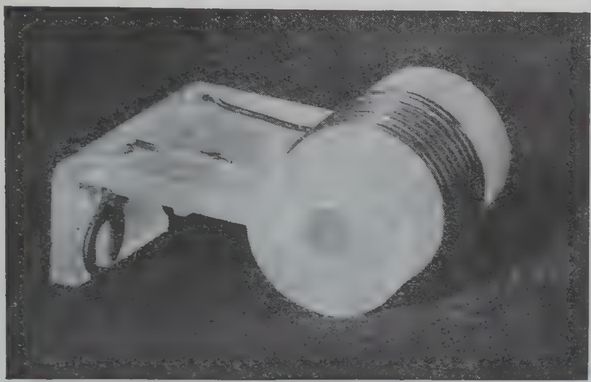


Fig. 1. R. f. measuring coil [1, 2 and 10 MC s] into which the test piece is put and its Q factor measured by a *QVH* type Q-meter

at the same frequency will correspond to the specific resistances of the test pieces.

The coil losses might also be taken into account by a corrective factor, if necessary. In case a homogeneous test piece, manufactured with utmost care is used as a reference, and its specific resistance at D. C. and at high frequencies is the same, then it is possible to determine, by this measurement, the specific resistance of the uppermost layer of the test piece, the depth of which does not exceed a few hundredth of a millimetre. The Q factor had been measured by a Rhode—Schwarz type QVH-BN 3672 Q-meter on approximately 10 MC/s. The measuring arrangement is shown on Fig. 2.

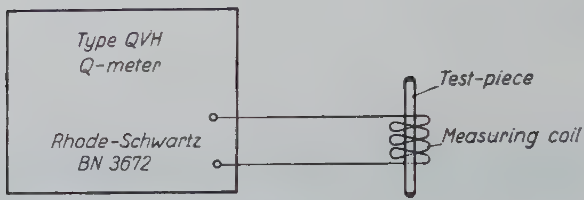
It can be theoretically shown, that if a core of infinite length and of $2\,r_0$ diameter is placed into an infinite coil of $2\,r_1$ diameter, and if the skin-depth of the core is δ, then the Q factor of the coil is determined by

$$Q = \frac{\pi\,(r_1^2 - r_0^2)}{2\pi r_0 \dfrac{\delta}{2}} \tag{1}$$

in case $\dfrac{r_0}{\delta} \gg 1$.

If the coil itself has losses, the resulting Q_r factor is given by

$$Q_r = \frac{Q_t \cdot Q}{Q_t + Q} \tag{2}$$



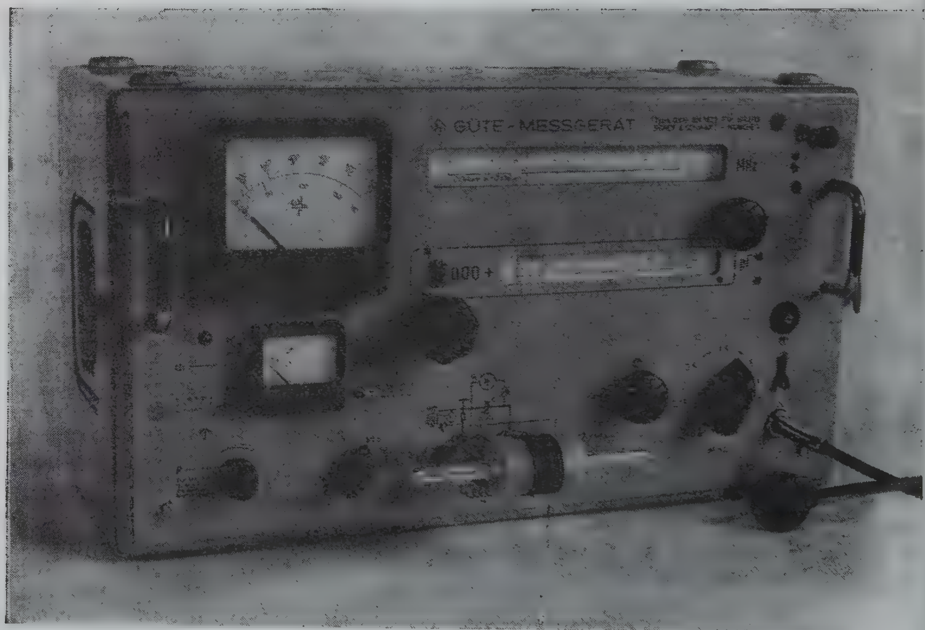


Fig. 2. Measurement of specific conductivity with a QVH type Q-meter

where Q_t is the Q factor of the coil, in case a core of the same diameter but made from a material with infinite conductance is placed into it. The specific conductance of the material that the core is made of can be calculated from

$$\sigma = \frac{Q^2}{r_0^2 \pi f \mu_0 \left[\left(\frac{r_1}{r_0}\right)^2 - 1\right]^2} \tag{3}$$

where f is the frequency used, μ_0 the permeability of the air.

2.2. *Measurement of specific resistance on microwaves*

The measurement of specific resistance is now restricted to measuring the Q factor of a coaxial cavity resonator. The cylindrical test piece acts as an inner conductor in a cavity resonator using the TEM mode, as is shown on Fig. 3. The inner conductor is shorter than the cavity itself and is placed

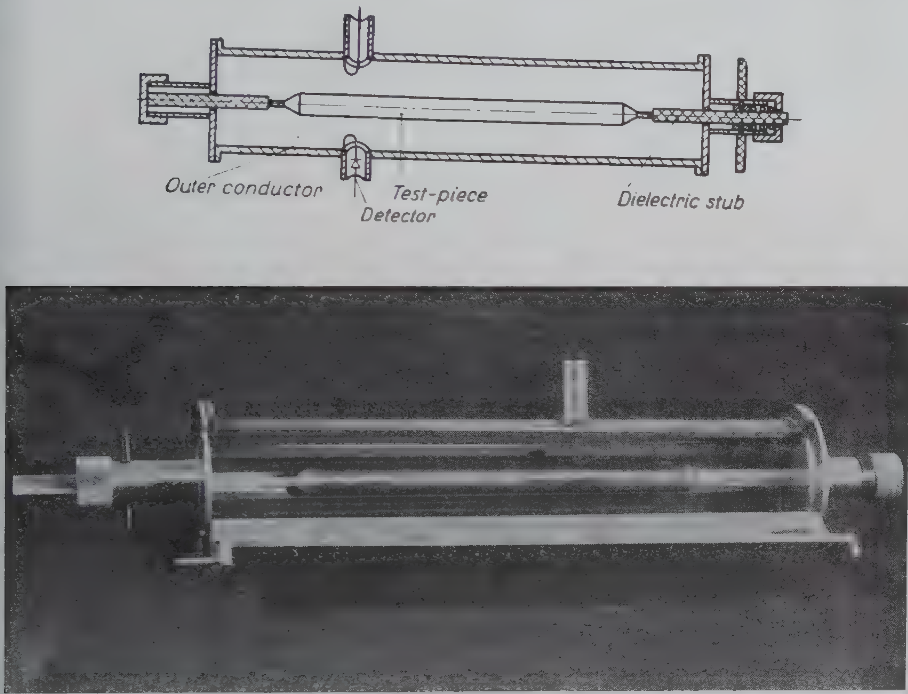


Fig. 3. Coaxial cavity resonator suitable for measuring specific conductance

in the middle. The cavity must be dimensioned in such a way, that the operating frequency band should lie below the cut-off frequency of the sections without an inner conductor. In this case these sections only cause a small capacitive load to the section having the inner conductor.

In this way there is practically a voltage maximum on both ends of the inner conductor. The length of the inner conductor is appr. an integer multiple of half of the wavelength at resonance. The true resonant wavelength is somewhat longer than the former theoretical value. A test piece of greater length might be examined at more than one frequency.

The advantage of the method discussed above lies in the fact, that there are no conduction currents between the inner and outer conductors, so all possibilities of bad or improper contacts have been eliminated. The test piece

is held by conical dielectric rods concentric to the cylindrical outer conductor. One of these conical dielectric rods is fastened to its place by a screw, while the other is pressed against the inner conductor by a spring. If this latter rod is pulled back against the force of the spring, the test piece is then easily accessible and can be taken out. The outer conductor is axially slotted and this slotted section, turning around one side, can be opened or closed like a door, which makes the easy handling of the test piece possible. Having closed this slotted section the remaining gaps have no importance for they are parallel to the wall-currents.

The Q factor of the cavity is:

$$Q = \frac{2 \ln \frac{b}{a}}{\frac{\delta_1}{a} + \frac{\delta_2}{b}} \tag{4}$$

$$\frac{1}{Q} = \frac{1}{Q_1} + \frac{1}{Q_2} \tag{5}$$

$$\frac{1}{Q_1} = \frac{\frac{\delta_1}{a}}{2 \ln \frac{b}{a}} \tag{6}$$

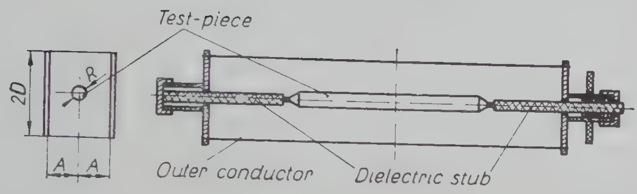
$$\frac{1}{Q_2} = \frac{\frac{\delta_2}{b}}{2 \ln \frac{b}{a}} \tag{7}$$

where a is the radius of the inner conductor,
b the radius of the outer conductor,
δ_1 the skin-depth in the inner conductor,
δ_2 the skin-depth in the outer conductor,
Q_1 the Q factor characteristic of the inner conductor,
Q_2 the Q factor characteristic of the outer conductor.

The maximum Q factor can be achieved if $b/a = 3.6$. As a is much smaller than b, the Q factor is determined mainly by the skin-depth of the inner conductor. The losses due to the outer conductor and the rods were experimentally determined and Q_2 was calculated from this. To secure the minimum possible error, however, the surface of the outer conductor has also been finished with utmost care.

The specific conductance measured on microwaves is given by:

$$\sigma = \frac{1}{\pi f \mu_0} \left[\frac{1}{2 a \ln \frac{b}{a}} \cdot \frac{Q_m \cdot Q_e}{Q_e - Q_m} \right]^2 \tag{8}$$



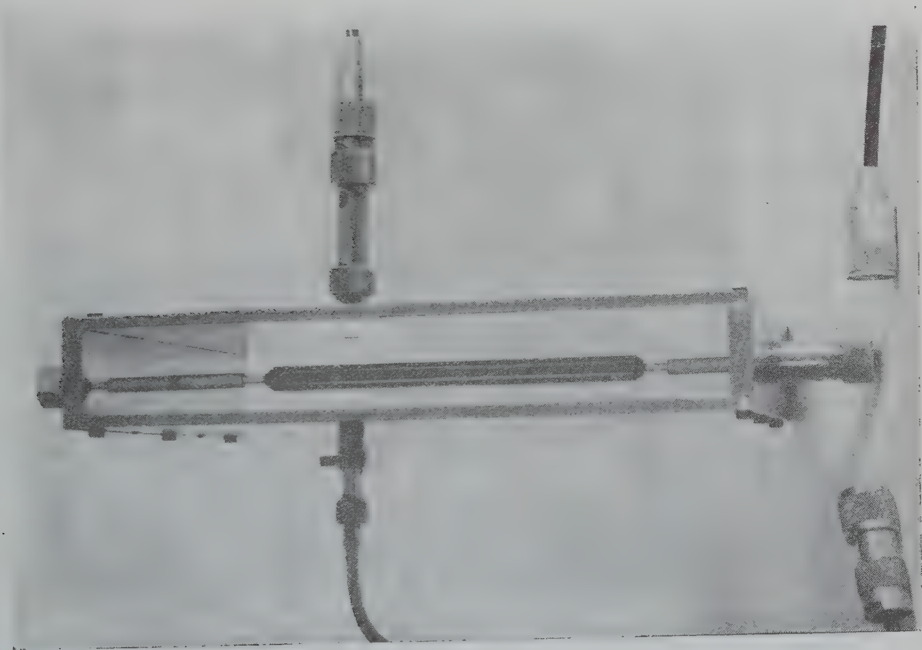


Fig. 4. Special cavity resonator suitable for measuring specific conductance

where f is the frequency,
μ_0 the permeability of the air,
Q_m the Q factor determined by measurement,
Q_e the Q factor characteristic of the equipment, determined during calibration.

Getting the test piece in and out becomes a great deal easier if instead of a cavity made of coaxial line another kind of resonator, consisting of the test piece between two parallel planes is used. This is shown on Fig. 4.

It is well-known that by using the complex function $w = \mathrm{tg}\, z$, the coaxial line can be transformed into a line consisting of a central conductor between two infinite parallel planes. In this transformed line the TEM mode is also possible, so a cavity of the same kind as was used above can also be made of it. If the resonator is made of finite planes instead of infinite ones, then by properly choosing the dimension marked $2D$, the equivalent gap on the coaxial line can be arbitrarily made small. According to calculations, the losses of the infinite planes are the same as the loss in the outer wall of a coaxial cavity, having an outer conductor diameter equal to the distance between the planes. The coupling of the microwave power into the cavity and out to the crystal detector is managed by coupling loops.

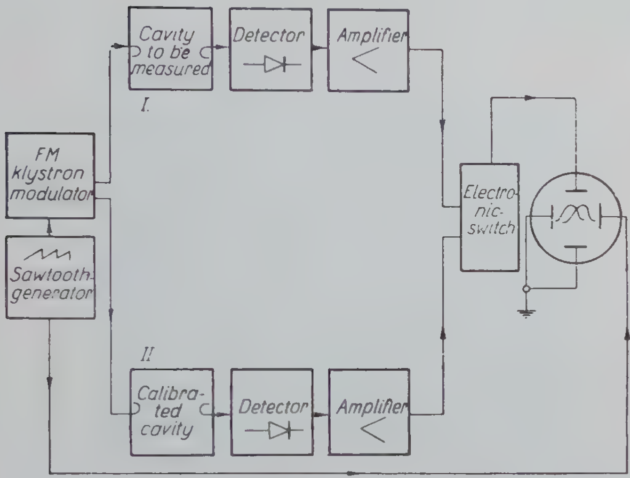
The Q factor of the cavity under test is measured and the conductivity of the test piece is determined by calculation.

$$\sigma = \frac{1}{\pi f \cdot \mu_0} \left[\frac{1}{2\, R \ln \dfrac{4\, A}{\pi\, R}} \cdot \frac{Q_m \cdot Q_e}{Q_e - Q_m} \right]^2 \tag{9}$$

where f is the frequency used at the measurement,
μ_0 is the permeability of the air,
A the distance between the planes,
R the radius of the inner conductor,
Q_m the Q factor determined by measurement,
Q_e the Q factor characteristic of the equipment, determined during calibration.

The cavity is compared to a calibrated one, the resonant frequency and Q factor of which can be set equal to those of the cavity under test. The measuring arrangement is shown on Fig. 5.

Both cavity resonators are fed by an oscillator FM modulated by a saw-tooth voltage. The average frequency of the oscillator is equal to the resonant frequency of the cavities. The frequency sweep is greater than the band width between the 3 db points. The a. c. voltage developed on the crystal detectors changes according to the resonance curves of the cavities. These signals are amplified and added together, before an electronic switch alternately lets one after the other onto the scope screen. Owing to the inertness of the eye, the two curves seem to appear simultaneously. By tuning the calibrated cavity to the same frequency of the tested one, the curves might be brought to overlap each other.



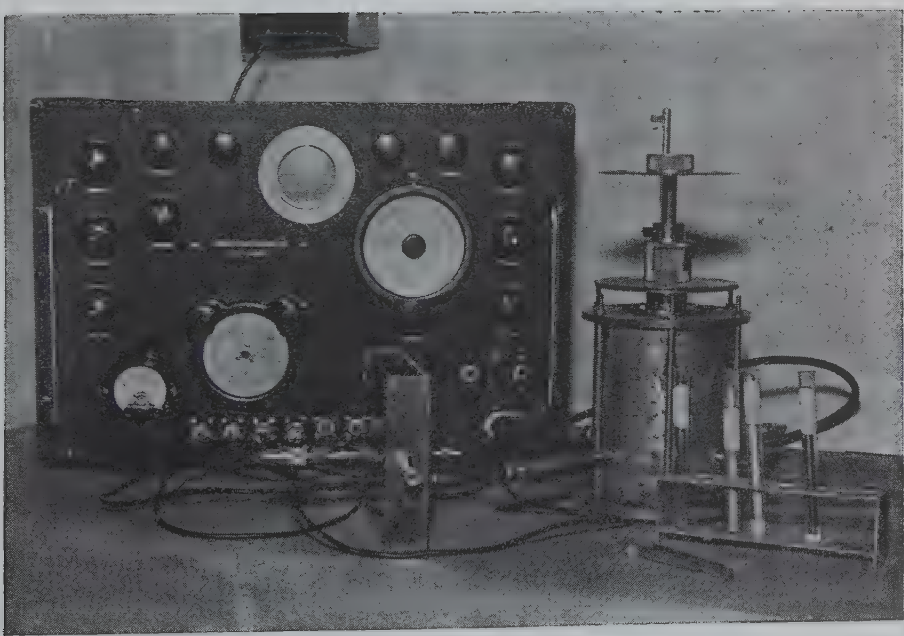


Fig. 5. Comparing the resonant curve of a microwave cavity resonator with that of a calibrated one

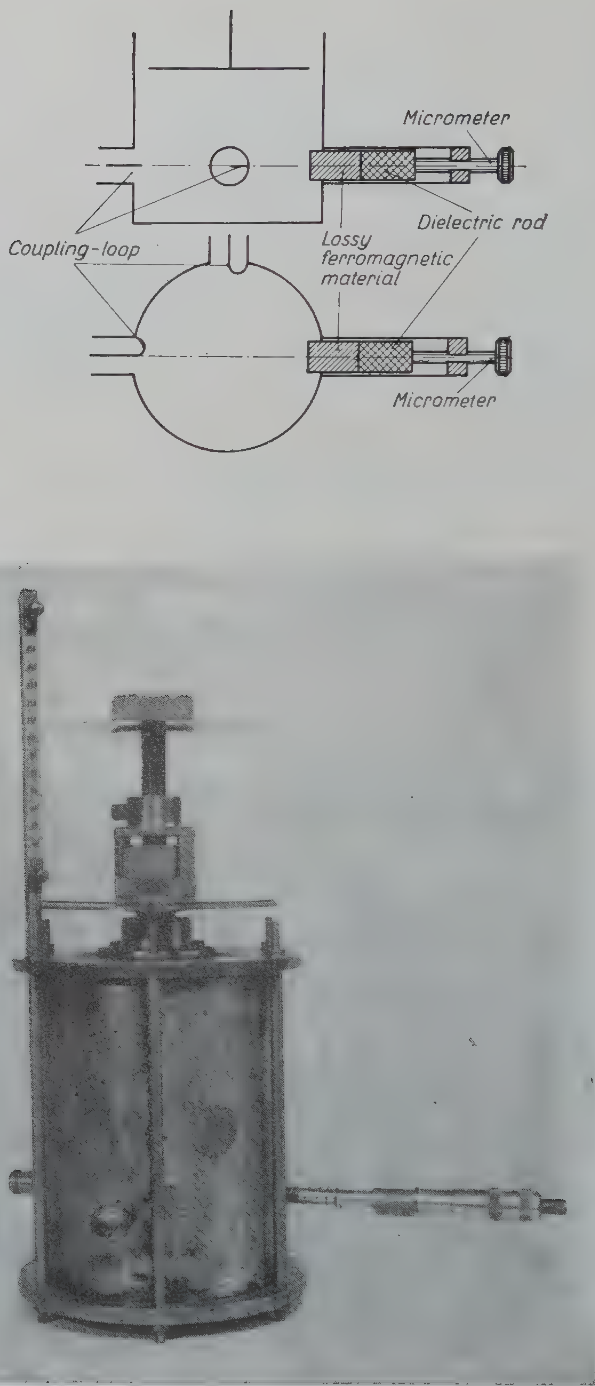
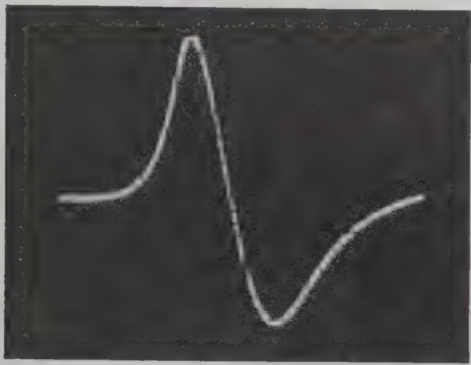
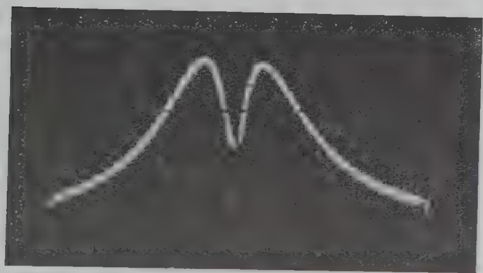


Fig. 6. **Cavity resonator with variable Q factor**

The calibrated cavity resonator is then so adjusted, that its Q factor takes up the same value as that of the one under test. This condition is fulfilled, when the two resonance curves overlap each other exactly. The Q factors of both cavities are now the same, and this values can be read off from the calibrated cavity resonator.



a



b

Fig. 7. Comparing the resonant curves of cavity-resonators on the scope-screen. *a)* the resonant frequencies of the two cavities are different, *b)* the Q factors of the two cavities are different

The cross-section of the calibrated cavity resonator is shown on Fig. 6. The cavity works in the TE_{011} mode and is tuned by a non-contacting top. The inputs and outputs are managed by coupling loops.

The Q factor of the cavity is made variable by placing ferromagnetic material inside the cavity. The position of this lossy iron-core material is adjusted by a micrometer.

Through proper dimensioning it is possible to change the Q factor without causing a drift of the resonant frequency.

At resonance, namely, the maximum electric and magnetic energies stored in the cavity are the same. If the altering made, when varying the Q factor, causes the same amount of change in both the magnetic and electric

fields, the resonant frequency remains the same, as is known from perturbation theory. The adjusting apparatus of the powdered-iron attenuator must not couple out electromagnetic energy from the cavity. The position of the powdered-iron material is therefore changed by way of a polystyrene rod which acts as a cut-off attenuator against the escaping energy. The value of the Q factor plotted against the micrometer divisions is determined by experimental calibration.

The fine frequency adjustment of this cavity is made by moving a polystyrene slug perpendicular to the cavity wall. The frequency drift is either calculated from the perturbation theory or determined experimentally.

The inevitable mistake committed during this method of Q factor measurement depends a great deal on personal judgement and the line width of the scope trace limits the otherwise considerably higher accuracy.

The accuracy of this measurement might be increased a great deal, if instead of comparing the resonance curves, their difference is examined. The voltages corresponding to the resonance curves, resp. are added up in opposite phases and this difference-signal is shown on the scope-screen, as it is given on Fig. 7. The summing up is carried out by the former electronic switch, after the driving signal is turned off, which previously controlled the switching. In this way the same apparatus might be used for both types of measurements.

It is advisable to follow the comparing method only when approximate data are needed, and to use the substraction method only if a high value of accuracy is necessary. To invert the phase of the voltage corresponding to the resonant curve of one of the cavities can be achieved in two different ways:

a) by using an inverse polarity crystal detector;

b) by switching-in a phase inverter stage in the row of the cascaded amplifiers.

The method discussed can be used not only for such tests as are mentioned above, but also for examining new cavities, transmission line joints.

During the course of our tests different technological methods were examined. Most of the experiments dealt with silver layers covered by different protective layers. Besides these, examinations were also carried out regarding natural aluminium, and aluminium alloys covered by different protective layers. The above-discussed method proved very useful when different test pieces were compared with each other, because its relative accuracy is extremely high.

The time reliability of the measurement depends solely on passive elements: on the time stability of the powdered iron core and on the micrometer.

Summary

The microwave surface roughness can be characterized by the ratio of specific resistances measured on microwaves and at very high frequencies, resp.

When measured at very high frequencies, the test piece is placed into a radio frequency coil and the resulting Q factor determines the specific conductance of the test piece. This same test piece can also be placed between dielectric bumpers in a cavity resonator, and this time the Q factor of the cavity will determine the specific conductance of the test piece on microwaves.

Writer designed a method for measuring the Q factors of resonant cavities, which is a quick and yet very accurate measurement, suitable for mass examination too.

The cavity under test is compared with a calibrated one and the differences of the resonant curves of the cavities are examined.

References

1. Morgan, S. P.: Effect of Surface Roughness on Eddy Current Losses at Microwave Frequencies. Journ. of Applied Physics. Vol. **20**, April, 1949. pp. 352—362.
2. Karboviak, A. E.: Theory of Imperfect Waveguides; the Effect of Wall Impedance. Proc. I. E. E. Paper No. 1841R. September, 1955. Part. B. pp. 698.
3. Kuhn, S.: Calculation of Attenuation in Waveguides. Journ. I. E. E. 1946. Vol. **93**, Part IIIA. pp. 663.
4. Benson, F. A.: Waveguide Attenuation and its Correlation with Surface Roughness. Proc. I. E. E. Paper No. 1467. March, 1953. Part B. pp. 85—90.
5. Benson, F. A.: Attenuation and Surface Roughness of Electroplated Waveguides. Proc. I. E. E. Paper No. 1518. July, 1953. Part B. pp. 213—216.
6. Allison, J., Benson, F. A.: Waveguide Surface Finish and Attenuation. Electronic Engineering. November, December, 1956. pp. 482—487, pp. 548—550.
7. Allison, J., Benson, F. A.: Surface Finish and Attenuation of Aluminium Waveguides. Electronic Engineering. January, 1957. pp. 36—38.
8. Allison, J., Benson, F. A., Seamen, M. S.: Characteristics of Some Ferrous and Non-Ferrous Waveguides at 27 Gc/s. Proc. I. E. E. Paper No. 2416R. November, 1957. Part B. pp. 599—602.
9. Allison, J., Benson, F. A.: Surface Roughness and Attenuation of Precision-Drawn, Chemically Polished, Electropolished, Electroplated and Electroformed Waveguides. Proc. I. E. E. Paper No. 1785R. March, 1955. Part B. pp. 251—259.

G. Almássy, Budapest XI. Sztoczek u. 2. Hungary.

ANGENÄHERTE QUADRATUR IM FALLE UNGLEICHER TEILINTERVALLE

Von

ZS. CSOMA

Physikalisches Institut der Technischen Universität, Budapest

(Eingegangen am 14. Oktober 1959)

In der Praxis sieht man sich oft vor die Aufgabe gestellt, ein bestimmtes Integral $I = \int\limits_{p_0}^{p_n} f(p)dp$ mit einer Annäherungsmethode zu berechnen, falls die Funktionswerte $f(p)$ mit nicht äquidistanten Abszissen p_i bekannt sind. So kann zum Beispiel $f = r^3p$ sein, worin p eine analytische Funktion von r bedeutet, deren Inverse aber mit elementaren Hilfsmitteln nicht darstellbar ist. In solchen Fällen gilt die Trapezsumme

$$T = \frac{1}{2}\left[(f_0+f_1)(p_1-p_0)+(f_1+f_2)(p_2-p_1)+\ldots+(f_{n-1}+f_n)(p_n-p_{n-1})\right] =$$

$$= \frac{1}{2}\left[f_0(p_1-p_0)+f_n(p_n-p_{n-1})+f_1(p_2-p_0)+\ldots+f_{n-1}(p_n-p_{n-2})\right]$$

nur als rohe Annäherung. Angenommen, $n = 2k$ sei eine gerade Zahl, dann benötigt man, um die Simpsonsche Regel anwenden zu können, eine zu einer neuen Variablen x führende Transformation, bei der die entsprechenden Teilintervalle gleich sind. Wenn die Funktion $f(p)$ z. B. tabellarisch gegeben ist, dann wird die Durchführung der prinzipiellen Transformation, die zum Integral $I = \int\limits_{x_0}^{x_n} f[p(x)]\,\frac{dp}{dx}\cdot dx$ führt, im allgemeinen Schwierigkeiten bereiten. Statt die Ableitung zu bilden, wollen wir zur Bestimmung des Integrals eine Annäherungsformel angeben.

Wir nehmen auf der x Achse äquidistante x_i mit der Schrittbreite $h = x_{i+1} - x_i$ an. Es sei im Falle $0 < i < n$ $\frac{p_{i+1}-p_{i-1}}{2} = \Delta p_i$; $p_1 - p_0 = \Delta p_0$ bzw. $p_n - p_{n-1} = \Delta p_n$.

Nun wählen wir eine Funktion $p(x)$ derart, daß $\left(\frac{dp}{dx}\right)_{x_i} = \frac{\Delta p_i}{h}$ sei. Geometrisch bedeutet diese Aufgabe, daß die Kurve der zu ermittelnden Funktion durch die gegebenen $n+1$ Punkte geht, wobei ihre Tangenten in den Anfangs-

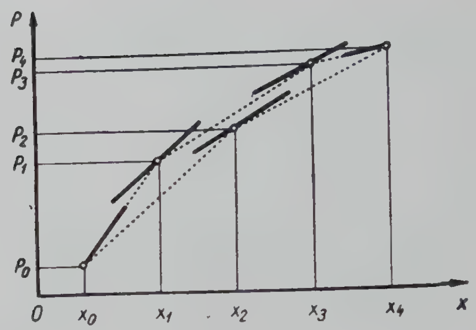


Abb. 1

und Endpunkten mit den entsprechenden Sehnen zusammenfallen, und in den Zwischenpunkten mit den die Nachbarpunkte verbindenden Sehnen parallel sind. Eine ganze rationale Funktion, die diese Forderungen erfüllt, ist leicht anzugeben. Die $2k+1$ Punkte und die zugehörigen Tangenten bestimmen ein Polynom $4k+1$-ten Grades. Für $k=1$ wird

$$p(x) = p_1 + A(x-x_1) + B(x-x_1)^2 + C(x-x_1)^3 + \\ + D(x-x_1)^4 + E(x-x_1)^5,$$

$$\frac{dp}{dx} = A + 2B(x-x_1) + 3C(x-x_1)^2 + 4D(x-x_1)^3 + 5E(x-x_1)^4,$$

$$p_0 = p_1 - Ah + Bh^2 - Ch^3 + Dh^4 - Eh^5;$$

$$\frac{\Delta p_0}{h} = A - 2Bh + 4Ch^2 - 4Dh^3 + 5Eh^4,$$

$$p_2 = p_1 + Ah + Bh^2 + Ch^3 + Dh^4 + Eh^5;$$

$$\frac{\Delta p_2}{h} = A + 2Bh + 3Ch^2 + 4Dh^3 + 5Eh^4,$$

$$\frac{\Delta p_1}{h} = A.$$

Aus diesen Gleichungen erhalten wir

$$B = \frac{3}{4}\,\frac{\Delta p_2 - \Delta p_0}{h^2}, \qquad C = 0,$$

$$D = -\frac{\Delta p_2 - \Delta p_0}{4h^4}, \qquad E = 0,$$

es ist also

$$p(x) = p_1 + \frac{\Delta p_1}{h}(x - x_1) + \frac{3}{4}\frac{\Delta p_2 - \Delta p_0}{h^2}(x - x_1)^2 - \frac{\Delta p_2 - \Delta p_0}{4h^4}(x - x_1)^4.$$

Ist $k > 1$, dann erfüllt die obigen Anforderungen eine Funktion, die je Teilintervallenpaar streckenweise aus je einem solchen Polynom vierten Grades besteht.

Wendet man zuerst die Trapezformel $T = h\left\{\frac{1}{2}(y_0 + y_n) + y_1 + \ldots + + y_{n-1}\right\}$ auf die Funktion $y = f\frac{dp}{dx}$ an, dann erhält man die schon in der Einleitung erwähnte Summe,

$$T = \frac{1}{2}\left[f_0 \Delta p_0 + f_n \Delta p_n + 2(f_1 \Delta p_1 + \ldots + f_{n-1}\Delta p_{n-1})\right].$$

Wendet man sodann auf die Funktion $y = f \cdot \frac{dp}{dx}$ die Simpsonsche Regel $S = \frac{h}{3}\sum_i s_i y_i$ an, wo $s_i = 1, 4, 2, \ldots 4, 1$, dann hat man

$$S = \frac{h}{3}\sum_{i=0}^{n} s_i f_i \frac{\Delta p_i}{h} = \frac{1}{3}\sum_{i=0}^{n} s_i f_i \Delta p_i,$$

in der die Variable x nicht mehr erscheint. Diese letzte Summenformel könnten wir die *verallgemeinerte Simpsonsche Regel* nennen. Eigentlich genügt es, sich auf $k = 1$ zu beschränken, wobei $s_i = 1, 4, 1$ ist. Beim Anschließen jedes neueren Teilintervallenpaars ist nämlich

$$f_{2k}(p_{2k} - p_{2k-1}) + f_{2k}(p_{2k+1} - p_{2k}) = 2f_{2k}\frac{p_{2k+1} - p_{2k-1}}{2}$$

das heißt von zwei anschließenden äußeren Teilintervallen wird ein einziges inneres Teilintervall gebildet.

Ist Δp_i konstant, dann erhält man die bekannte Formel wieder, denn es ist jetzt $p = x$, also $\Delta p_i = h$.

Wendet man nun die neue Regel auf den Fall $f(p) \equiv C$ konstant an, dann wird

$$S = \frac{1}{3} C \left[p_1 - p_0 + 2(p_2 - p_0) + p_3 - p_1 + \cdots + \right.$$

$$\left. + 2(p_n - p_{n-2}) + p_n - p_{n-1} \right] = C(p_n - p_0),$$

was mit dem Integral $I = \int\limits_{p_0}^{p_n} C dp$ genau übereinstimmt. Dieses Ergebnis läßt sich auch so formulieren, daß die Summe der den Ordinaten f_i zugehörigen Gewichte $\frac{1}{3} s_i \Delta p_i$ dem Grundintervall gleich ist.

Diese letzte Tatsache bestätigt die obige Definition von Δp_i.

Eine strenge *Fehlerabschätzung* genügt für $k = 1$, weil der Fehler für $k > 1$ aus den Fehlern der einzelnen Teilintervallenpaare zusammengesetzt ist.

Bekanntlich gibt die Formel

$$I - S = H = -\frac{h^5}{90} y^{(4)}(\xi)$$

den Fehler der Simpsonschen Regel an; ξ ist hierbei ein geeignet gewählter Wert zwischen x_0 und $x_0 + 2h = x_2$.

In diesem Falle ist $y = f \frac{dp}{dx}$, und wenn f', f'', f''' und $f^{(4)}$ die Ableitungen von f nach p bzw. p', p'', p''' und $p^{(4)}$ die Ableitungen von p nach x bezeichnen, dann ist

$$H = -\frac{h^5}{90} \{ f^{(4)} p'^5 + 10 f''' p'^3 p'' + 10 f'' p'^2 p''' + 15 f'' p' p''^2 +$$

$$+ 10 f' p'' p''' + 5 f' p' p^{(4)} \},$$

denn $\frac{d^5 p}{dx^5} \equiv 0$. Wie man sieht, bleibt bei gleichen Teilintervallen nur das erste Glied übrig, bei $f =$ konstant ist dagegen $H = 0$. Im allgemeinen erhält man eine obere Schranke für $|H|$, wenn man die Maxima der Absolutwerte der sechs eingeklammerten Glieder summiert. Dazu muß man die Ableitungen von f nach p, oder mindestens die oberen Schranken ihrer Absolutwerte kennen. Für die Ableitungen von $p(x)$ läßt sich aus den Formeln

$$p' = \frac{\Delta p_1}{h} + \frac{\Delta p_2 - \Delta p_0}{h^2} (x - x_1) \left[\frac{3}{2} - \frac{(x - x_1)^2}{h^2} \right];$$

$$p'' = 3 \frac{\Delta p^2 - \Delta p_0}{h^2} \left[\frac{1}{2} - \frac{(x - x_1)^2}{h^2} \right],$$

$$p''' = -6 \frac{\Delta p_2 - \Delta p_0}{h^4} (x - x_1); \qquad p^{(4)} = -6 \frac{\Delta p_2 - \Delta p_0}{h^4}$$

unschwer bestimmen, daß

$$|p'| \leq \frac{\Delta p_1 + 0{,}5\,|\Delta p_2 - \Delta p_0|\sqrt{2}}{h}; \ |p''| \leq \frac{3}{2}\,\frac{|\Delta p_2 - \Delta p_0|}{h^2};$$

$$|p'''| \leq 6\,\frac{|\Delta p_2 - \Delta p_0|}{h^3}; \ |p^{(4)}| = 6\,\frac{|\Delta p_2 - \Delta p_0|}{h^4}.$$

Da h^5 in den Nennern der einzelnen Glieder vorkommt, erscheint h in der oberen Schranke von $|H|$ nicht mehr. Wie man sieht, läßt sich mit der Verminderung der Differenz zweiten Grades $|\Delta p_2 - \Delta p_0|$ im Verhältnis zu Δp_1 auch die Fehlerschranke vermindern.

Wird die Zahl k bei gegebenem Grundintervall $p_n - p_0$ hinreichend groß und das größte Teilintervall hinreichend klein, dann folgt aus der Beschränktheit der Ableitungen von f, daß die Fehlerschranke beliebig klein werden kann.

Sind in der Praxis die Ableitungen von f unbekannt oder verursacht ihre Berechnung zu große Schwierigkeiten, dann bewährt sich bei hinreichend großem k einere andere, weniger strenge Fehlerabschätzung. Der Fehler der ursprünglichen Simpsonschen Regel läßt sich im Absolutwert mit der folgenden Formel annähern, wenn man die Ableitung durch den Differenzenquotienten ersetzt:

$$E = \frac{kh}{90} \cdot \max|\Delta^4 y_i| = \frac{kh}{90} \max|y_{i+4} + y_i - 4\,(y_{i+3} + y_{i+1}) + 6y_{i+2}|,$$

$$i = 0, 1, 2, \ldots 2k - 4.$$

Aus dieser Formel wird in unserem allgemeinen Fall

$$E = \frac{kh}{90} \cdot \max|\Delta^4 (f_i \Delta f_i)| =$$

$$= \frac{k}{90} \max|f_{i+4}\,\Delta p_{i+4} + f_i\,\Delta p_i - 4\,(f_{i+3}\,\Delta p_{i+3} + f_{i+1}\,\Delta p_{i+1}) + 6 f_{i+2}\,\Delta p_{i+2}|.$$

Die Anwendung der letztgenannten Formel erhellt aus folgendem einfachem Beispiel, wobei auch I exakt berechnet werden kann. Es sei

$$f = \frac{1}{p}, \quad p_0 = 0{,}2; \quad p_n = 2; \quad I = \int\limits_{0,2}^{2} \frac{dp}{p} = \ln 10 = 2{,}30259\ldots \qquad n = 8$$

$k = 4$

p_i	Δp_i	f_i	$f_i \Delta p$	$s_i f_i \Delta p_i$	$\Delta^4 (f_i \Delta p_i)$
0,2	0,2	5,0	1,000	1,000	
0,4	0,15	2,5	0,375	1,500	
0,5	0,1125	2,0	0,225	0,450	+0,124375
0,625	0,15	1,6	0,240	0,960	+0,2025 max.
0,8	0,1875	1,25	0,234375	0,46875	+0,01125
1,—	0,225	1,0	0,225	0,900	−0,073125
1,25	0,3	0,8	0,240	0,480	+0,036875
1,6	0,375	0,625	0,234375	0,93750	
2,—	0,4	0,5	0,200	0,200	
				6,89625 : 3	

$T = 2{,}37375 \qquad S = 2{,}29875$

Der wirkliche Fehler ist $H = 0{,}00374$ (ca. $1{,}6^0/_{00}$).
Mit der letzteren Fehlerabschätzung wird $E = 0{,}009$.

Es ist zu bemerken, daß E im allgemeinen nicht immer größer ist als $|H|$. Jedenfalls läßt sich behaupten, daß auf Grund der vorausgesetzten Stetigkeit von f bei hinreichend großem k und hinreichend kleinem maximalen Δp_i, $|H|$ mit E beliebig klein werden kann.

Zusammenfassung

Die bekannte Trapezformel gibt bereits eine Annäherungsmethode für ein bestimmtes Integral im Falle ungleicher Teilintervalle. Eine genauere Annäherung ermöglicht die Verallgemeinerung der Simpsonschen Regel für diesen Fall. Es werden zwei Fehlerabschätzungen angegeben, auch wird ein einfaches Beispiel gezeigt.

Literatur

1. Bjesikovitsch, J. S.: Közelítő számítások. Tankönyvkiadó, Bp. 1952. S. 222.
2. Kopal, Z.: Numerical Analysis. Chapman and Hall. London. 1955. S. 345.
3. Scarborough, J. A.: Numerical Mathematical Analysis. Oxford University Press. London. 1955. S. 131.

Zs. Csoma, Budapest XI. Budafoki út 8, Ungarn.

SOME PROBLEMS OF THE LONG-RANGE PLANNING OF LABOUR PRODUCTIVITY IN INDUSTRY*

By

G. Cukor

Institute for Economics of the Hungarian Academy of Sciences

(Received September 3, 1959)

The issues of labour productivity are discussed in several connections in economic literature. The concept of productivity, the problems of measuring and the relations between productivity on the one hand, and costs, prices and wages on the other, are considered. The rate of increase in productivity, and hence, the development of one or other branch of industry or the entire industry of a country is analysed and comparisons are made of the level of productivity in various enterprises and even in various countries. Much attention is devoted to the resources and ways of increasing labour productivity and this aspect of the subject of productivity, partly overlaps with those of technical development, and the improved organization of production.

The productivity of labour plays a special role in the economic planning of the socialist countries. The main aim of this planning is to develop productive forces rapidly and proportionately, in order to raise the standard of living of the population. All relations that reflect the development of the productive forces are, therefore, especially important to the planning and the measurement of the results of economic development.

Increases in the productivity of labour can be regarded as a sort of "qualitative" aspect of the development of productive forces, as opposed to the quantitative aspect, — represented mainly by the numbers of those engaged in production and the volume of equipment and machinery used in production. (The qualitative and quantitative aspects are, of course, very closely interrelated and their separation is arbitrary and only permissible to show the significance of the productivity of labour.)

Productivity is usually considered in respect to one plant, a branch of industry, the whole of industry or the whole of the economy. It may be planned for a brief period (*e. g.* one year) or a longer one (5, 10 or 15 years). The aim of this paper is mainly to deal with the problems of planning productivity

* A paper presented at the Conference on the Problems of Labour Productivity, organized from 29th Sept. to 2nd Oct., 1959, by the Department for Social and Historical Sciences and the Institute for Economics of the Hungarian Academy of Sciences.

for the whole of industry or for particular branches over longer periods of time. In order to promote discussion of these issues they are discussed mainly with respect to the theoretical relations involved, rather than from the point of view of direct, practical application.

*

1. Compared to the literature on other problems of productivity, such as the measurement of productivity and the connection between productivity and wages, *sources on the planning of productivity are not particularly plentiful.*

The literature of the socialist countries emphasizes the importance of planning and points out that the planning of increases in productivity takes place on the basis of an analysis of the factors that influence the development of productivity.[1] These factors are the technical level (mechanization, automation), the improved organization of labour processes, greater skill, improvements in material and cultural standards of the working people, the wage system, the workers' attitude to their work, socialist labour emulation, etc. The sources, however, — in accordance with practical experiences of planning — hasten to point out, that though the effect of these factors on productivity is obvious, it is equally obvious that this effect cannot be numerically evaluated and calculated in planning, because the connection between the plans for labour power and those for technical development cannot be determined and planning methods that make it possible to show the connection between the better organization of labour and productivity have not yet been evolved. The situation is similar with respect to productivity on the one hand, and skill, material and cultural level, the wage system, labour discipline, etc. on the other.

The problems of long-range planning are also of interest to the economists of those capitalist countries, where there is no planned economy, and even the idea of one is officially rejected. Here too, it has proved desirable to become acquainted with expected economic trends in order to shape economic policies (whether they be those of governments or of the larger monopolies). Official and unofficial commissions are given for the preparation of long-range forecasts and the most suitable methods of preparing them are studied. Naturally, the expected development of labour productivity plays an outstanding part in their preparation. One of the foundations of these forecasts is the development of the national income, which may be determined from the projected employment figures and productivity. Projection takes place on the basis

[1] *Q. v.*: Az ötéves terv felülvizsgálatának tervezési kérdései (Planning problems of the revision of the Five Year Plan). Tervgazdasági Könyvkiadó, Budapest, 1951.— A népgazdaság tervezése (Planning the people's economy). Marx Károly Közgazdaságtudományi Egyetem, Felsőoktatási Jegyzetellátó Vállalat, Budapest, 1955. — A népgazdasági tervezés egyes kérdései (Some problems of planning the people's economy). Tervgazdasági Könyvkiadó, Budapest, 1951.

of the trend of development,[1] but it was pointed out that such an extrapolation of development over the past period presumes that the effect of changes in the structure of the national economy, the rate of increase of capital per worker and the effectiveness of expenditure on research and development, will remain unchanged. These assumptions can, however, hardly be accepted, especially over a longer period of time.

The literature of the socialist countries, therefore, mainly emphasizes the analysis of factors affecting changes in productivity, while pointing out that due to the highly complex relations between these factors and the development of productivity, the quantitative evaluation of the effects is very difficult. In the capitalist countries — since they have no system of economic plans at their disposal — attempts are made to extrapolate from curves of development over longer periods of time, while generally recognizing that extrapolation involves the assumption of the constancy of the effects and relations obtaining in the previous period, an assumption which is untenable in practice.

2. It is a familiar fact that the basis of long-range planning — as, indeed, of economic planning in general — is the method of balances which gives a check on whether the equilibrium and desired proportions of the economy are secured during the course of the planned development. Each balance may, however, only contain quantities of one dimension. Balances of the national income are, for instance, expressed in money, those of labour power in numbers employed or in hours of labour and those of materials in some sort of natural unit. The various balances only form a homogeneous system of balances for the people's economy if they are inter-linked and the link between them is obviously part of the method of balances. Indices of the productivity of labour provide just such links between the various balances. The index of labour productivity provides a link between the balance of labour power and that of the national income and — if properly used, in the right place — between the balance of labour power and the various balances of products. The links between the different balances are ratios. The indices of productivity are also ratios between the product and the amount of labour used to produce it. These ratios, however, change parallel with technical and economic development and the changes in them considerably influence the equilibrium of the people's economy, as reflected in the system of balances. In order to determine the extent of these changes it is necessary to plan the ratios concerned, in the present case the indices of labour productivity.

In the case of long-range planning the projection of productivity may be of two types. Planning in general is based on planning an increase in production, where the point of departure is given by known limitations, the

[1] *E. g.* Long-Range Economic Projection. Studies in Income and Wealth. Volume Sixteen. National Bureau of Economic Research. Princeton University Press. p. 67.: National Productivity and its Long-Term Projection, by John W. Kendrick.

bottlenecks of economy. A "technical" barrier of this sort to increasing production might, for instance, be the capacity of the productive equipment. This capacity is given and the added capacity to be installed over the next period of, say, 3—5 years may also be fairly accurately determined. Knowing these capacities it may also be established — at least with respect to the most important materials — to what extent the supply of materials imposes a limit on the expansion of production. In the case of a small country like Hungary, of course, imports (and perhaps also exports) must be taken into consideration as regards the supply of materials. The main consideration in increasing exports is again the trend of the balance of foreign trade. In all these calculations attention must also be paid to the expected effect of technical progress, as a result of which the capacity of certain items of equipment may increase, or the specific requirements of materials or power of some processes may decrease, so that production can be expanded not only at the technical level of the period concerned, but also at a higher level. All these changes may, however, over a period of a few years be more or less precisely estimated. (Except for those branches of industry, where the products or the productive processes rapidly change, as in engineering or some branches of the chemical industry.)

The above considerations then permit the level of production over the period of the plan to be determined. *In planning of this type the indices of productivity serve to check the correspondence between the labour power plan or labour power balance and the production plan and may be planned once the level of production, the investments etc., are known for each branch of industry.*

If the plan is prepared not only for 3—5 years, but for a longer period, 10—15 years, then the bottlenecks and technical limitations mentioned may no longer be taken as bases for calculation. In the previous case the plan is determined to a much greater extent by existing capacity, the structure of production, etc. while when planning over 10—15 years there is much more opportunity for choices to be made in regard to the direction and rate of development. *Here* — at least in respect to the first calculations — *the expected rate of increase in productivity may be a basic hypothesis for planning* which, together with employment figures calculated from demographic statistics, determines the national income, the volume of production, etc. It is then on the basis of data thus obtained that the figures for the production of power and of some of the main materials, for imports and investments and changes in the industrial structure, or various combinations of all these factors may be computed, so as to secure the proportionate development of the people's economy, the investments necessary for further development and the planned increase in the standard of living.

The various calculations cannot, of course, (at least as far as we know at present) be carried out in one step. Certain connections and ratios have

to be postulated at the outset and it could be that the calculations do not verify these assumptions. There is, for instance, an interrelation between labour productivity and the possibilities of investment. A given level of productivity, together with the number of employed persons yields the national income, which in turn determines the volume of investments. The latter strongly affects the opportunity for further enhancing productivity.

3. The indices of labour productivity used in planning are ratios between production and the (live and embodied) labour used in production. They could, theoretically, be directly planned, by planning the "labour requirement" *i. e.* the total direct or indirect labour time and material consumption in the above sense for a certain product several years ahead. Such direct planning is, however, not practicable. The productivity figures used in long-range planning — as indeed those used in any *economic* investigation — are, in their content, *average productivities*. The productivity figures for a particular factory are averages for several products, those for a branch of industry, for several factories and those for the whole of industry are averages for several branches. Moreover, since it is usual to operate with productivity figures for a longer period, generally for at least one year, all figures for productivity are average values over a lengthy period of time. In order, therefore, directly to plan productivity it would be necessary to have full details on the structure of production over the period of the plan. Even the "labour requirement" of a *single product* cannot in every case be directly planned over a lengthy period. Apart from the fact that the labour requirement (and production costs) for a product are very often themselves functions of the choice of products available, the level of productivity depends on so many technical, economic and social factors that it does not seem possible either to become acquainted with all these factors or, on the basis of such an acquaintance, to plan labour requirements in detail directly. It is obvious enough that, even if the technical level is identical, productivity will vary for differing exploitation of the capacity available or different levels of labour skill. The specifically technical factors may themselves also differ, *e. g.* productivity would be different if the same machinery were used with materials of a different quality.

Due to the very large variety of factors affecting the level of productivity, it is easier to plan *changes* of *productivity*. Here it may be presumed that a part of the factors affecting production will remain unchanged, or will change but slightly and it is sufficient to investigate the changing factors and evaluate the effects of the changes.

4. All long-range economic plans, including therefore plans for the productivity of labour, are based on figures from the past which thus serve as points of departure for planning and at the same time as first checks on the figures of the plan.

The initial data of planning are

a) productivity figures for a certain period, the so-called base period of time (generally one year), together with all the circumstances under which that particular level of productivity came about, *i. e. extremely detailed* facts on the structure of production, the technical level, the quality of the labour power, etc. It is also necessary to know

b) the trend of the development of productivity up to the base period for several years retrospectively, together with the main factors affecting the development of productivity.

What are the requirements that planning has to formulate in respect to these initial data?

The ideal would be if the homogeneity of the figures from the point of view of structure could be secured with adequate precision, *i. e.* if, for instance, the figures for what is regarded as a homogeneous branch of industry did not include products with greatly differing requirements of labour and materials. Since this aim cannot be attained, an effort must be made to try and constitute groups from the figures, within which the effect of the main factors influencing productivity should at least be of the same order of magnitude. This requirement is usually fulfilled if the figures are sorted according to statistical classification of the branches of industry and their sub-groupings.

A requirement that is easier to fulfil — though not always complied with in statistical practice — is that the membership of the various groups should be identical or at least identifiable. This means that a particular group (*e. g.* a branch of industry) should always include the same enterprises, or at least that the effects of changes should be registrable and calculable, and that there should be no interruption in the chronological sequence of the figures.

5. The planning of productivity may thus take place on the basis of the *factors* of the changes in productivity. If the development of these factors and the relations (functional connections) between the factors and the level of productivity were precisely known, then changes in the level of productivity could, without particular difficulty, be computed. Unfortunately, neither of the above two conditions is generally completely fulfilled. It is true that the main factors (even though not all, *without exception*) affecting the growth of productivity are known, but there is only qualitative knowledge of the relations between these factors and productivity, *i. e.* it is only known whether changes in these factors tend to increase or to decrease productivity, but there is no quantitative knowledge to reveal the degree of the effect. Even changes in the greater part of the factors affecting the growth of productivity cannot be quantitatively expressed.

Economic literature contains abundant discussions of factors of changes in productivity, or rather of the causes that result in changes of productivi-

ty.[1–5] Because of the complex connections and interrelations of the phenomena of the people's economy it is really more difficult to find one that does *not* affect the productivity of labour (and that is not affected by that productivity), than one where this is the case.

If the various details are not considered, the following factors, or rather groups of factors appear to be most significant: the *a)* technical level, *b)* the use made of available capacity, *c)* the skill of the workers (quality of the labour power), *d)* welfare and social factors, *e)* natural factors.

Let us briefly consider what is meant — at least with respect to productivity — by each of the above factors and how their effect on labour productivity could be determined.

a) It is obvious that productivity is, in the first place, determined by the quantity and quality (effectiveness) of the instruments of production used and the efficiency of their utilization, *i. e.* the *technical level.* Among the instruments of production it is the implements of labour, *i. e.* the machines and tools directly used in production, that exercise the greatest and at the same time the most direct influence on productivity, for their technical development is precisely manifested in that a greater volume of use value can be produced with the same quantity of labour. This means that changes in labour productivity are directly determined by the development of the machinery of labour (of machine tools in the general sense). The development of prime movers also has an important but indirect effect on the productivity of labour.

In order, however, to be able to plan, using the technical level, the quantitative relations, some sort of functional connection should first have to be determined. To do this, the technical level itself would first have to be numerically measured, as one of the "independent variables" of the function. The whole of the technical level cannot, however, be numerically measured (though partial indices, of course can), — in fact, it is the index of labour productivity that permits the best approximation to its development. It is not much use trying to measure, not the technical level directly, but — in the sense of the foregoing — the quantity and effectiveness of the implements of labour, *i. e.* the machinery used. The "quantity" of machinery and equipment — in so far as it affects productivity — cannot be measured for the whole of industry

[1] *Q. v.*: A Közgazdaságtudományi Egyetem népgazdaság tervezése jegyzete (Notes on Planning the People's Economy at the University for Economics). Felsőoktatási Jegyzetellátó Vállalat, Budapest, 1955.

[2] Fritz Behrens: "Die Arbeitsproduktivität". Fachbuchverlag, Leipzig, 1955.

[3] Dr. István Varga: Adalékok a magyar gyáripar konjunkturális helyzetének alakulásához (Contributions on the trend of the prosperity of Hungarian manufacturing industries). Paper No. 8 of Magyar Gazdaságkutató Intézet, Budapest, 1935.

[4] Measurement of Industrial Productivity. The World Press Ltd., Calcutta, 1955.

[5] Bureau International du Travail. Méthodes d'établissement des statistiques de la productivité du travail. Genève, 1951.

because it is not homogeneous and cannot be expressed in similar units, so that it cannot be added. The number of items of machinery can, of course, be established, but since machines of differing performance and even producing different products are used, there is no direct relation between changes in the number of items and in productivity. The quantity of implements of labour could also possibly be established according to their value, or more precisely their prices. The effect on productivity of items of equipment of identical price is, however, also not identical. (Nevertheless, an analysis of the net value of machinery and the value of newly set up machinery and the subsequent development of productivity might, of course, provide useful information.)

It is usual in investigations of the development of productivity to seek connections between productivity and the numbers of prime movers and electric motors or their horse-power. These latter quantities are usually systematically shown in industrial statistics. As the units are congruent, they may be added and the increase in horse-power undoubtedly expresses the increase in the volume of machinery, and generally also, its enhanced performance and modernity, since the more productive types of machinery usually have larger (and sometimes more) motors. The increase in the volume and performance of machinery is roughly proportional to the increase in power requirements, in the horse-power of the prime movers and in power consumption, so that these may also to some extent serve as measures of the volume of productive equipment: this measure is, however, indirect and rather inaccurate. It does not take into account the modernity, age and the quality generally, of the actual productive equipment, the machinery itself. The relation between production per worker and the horse-power of electric motors per worker is, therefore, not close and not unequivocal. Rostas finds[1] that in a comparison of 28 branches of industry in the United States and Britain, a close liaison between productivity and the number of horse-powers per worker could only be established in 6 cases.

There is a closer connection between changes in productivity and the number of horse-powers per worker within the industry of one particular country,[2] but even there it is not close enough to be applicable in planning.

[1] L. Rostas: Comparative Productivity in British and American Industry. (Cambridge University Press.)

[2]

	Britain 1924—1930	United States 1924—1937
Annual increase in productivity, p. c.	2.3	3.3
Increase in HP/worker of electric motors, HP	0.075	0.15

Ibid. p. 52.

The influence of productive equipment on productivity is different for each branch of industry. There are branches, such as the chemical industry, paper milling and electric power production, where the machinery more or less unequivocally determines technology, and this, in its turn, productivity. Here the installation of new machinery — at least of new machines that could have an important effect on productivity — takes several years, because equipment of this type is, throughout the world manufactured only by orders, and delivery times are very long. In such branches, therefore, a knowledge of the investment plans or of the orders already placed makes it definitely possible to determine when the new, more modern productive capacities will become available, *i. e.* when a change in productivity due to the installation of new machinery may be expected. In other industries, such as engineering, textiles and shoes, new machines may very speedily be installed. Here, however, the installation of one or other new machine or piece of equipment does not in itself involve a substantial change in productivity. It is, therefore, necessary to find out to what extent the expected investmens effected will change the volume, composition, quality and modernity of the machinery.

The volume and condition of the machinery and equipment does not in itself unequivocally determine the technical level. Changes may take place in the technology, the manufacturing process and the materials used may also vary.

It is obvious that next to the machines, productivity is most influenced by the other group of the instruments of production, the materials (the objects of labour). These generally change more slowly than the machinery that is used to process them, and thus their effect on productivity is smaller.

Changes in the materials may influence the growth of productivity in two ways. First, if the material remains the same, its chemical, physical and technological properties do not essentially vary, but the qualitiy of the material changes and this results in increased productivity. If, for instance better quality cotton is used, or the yarn spun from the cotton is better, there will be fewer breakages on the loom; if milled goods are of better quality they are easier to machine or to draw; if castings are of better quality they can be more easily worked and there are fewer rejects.

Changes of this type may — at least in general terms — be estimated several years ahead for a particular factory or possibly even for a branch of industry. Such an estimate is, however, hardly possible for the whole of industry.

The change in materials exercises a greater influence on productivity if new materials appear, whose processing technology, mechanical and physical properties differ from those previously encountered. The various synthetic materials that are increasingly used instead of metals or wood and in the textile industry, are a case in point. The use of these materials generally involves a considerable change in the technology of production and may thus very

greatly enhance productivity. The introduction of these synthetic materials does not, however, take place overnight but takes a number of years, so that the effect on productivity can be determined. The relations pertaining in a particular factory or branch of industry may here again be fairly clearly established, though this is considerably more difficult in the case of comprehensive planning for the whole of industry.

b) Changes in *the utilization of productive capacity* are mainly mentioned in bourgeois sources as very important factors of the changes in labour productivity. One part of the theoretical basis for a connection between the utilization of capacity and productivity is the U-shaped cost function familiar in western economics. According to this, the relation between costs and the volume of production may be graphically represented by a curve where costs increase, both to the right and to the left of a certain optimum, *i. e.* if the volume of production is either smaller or larger. In consequence of the close connection between costs and productivity, it is obvious that if this U-shaped cost function really exists, then there is a similar functional relation between productivity and the volume of production. The other connection is the postulate of bourgeois economics that if demand drops, those plants that have higher production costs shut down, while if production is increased, they are re-opened.

Both these phenomena do in fact exist in respect to certain branches of industry or particular firms, but are not generally valid and cannot be established as "macro-economic" relations for the whole of industry. If the development of production and of productivity in the United States between 1924 and 1938 is compared,[1] the following connection is found:

decreasing	production	decreasing	productivity	for	2	years
decreasing	production	increasing	productivity	for	2	years
increasing	production	increasing	productivity	for	6	years
constant[2]	production	constant	productivity	for	3	years

If the gross value produced per head for Hungarian industry between 1927 and 1943 is considered, it is found that from 1930 to 1933, *i. e.* during the years of economic crisis, the decrease in production was accompanied by a simultaneous constant increase in productivity. The Hungarian Economic Research Institute attributed this fact to the shutting down, as a result of the crisis, of the plants operating with lower productivity. The increase in productivity was, however, not a real one but occasioned by a change in the structure of production, for during this period production by the iron, steel and metal industries and by engineering decreased considerably; there was a smaller decline in the food processing industries but, after a slight depression,

[1] Kendrick, op. cit., f. pp. 82—83.
[2] Changes of about 1% being neglected.

there was an increase even during the crisis of production in the textile, chemical and electric power industries — to mention only the more important branches. If the relations are examined industry-by-industry it is found that in the branches where production considerably decreased there was generally also a decline in productivity, lesser decreases in production were accompanied by a smaller decline in production and increased production generally involved increased productivity. The apparent increase in productivity for the whole of industry is due to the fact that production (and productivity) increased in just those branches of industry, where the value produced per head was high. (If an unvarying index is weighted by the numbers employed, there is no longer a growth of productivity between 1930 and 1933.)

It may, therefore, in general terms be stated of the connection between the utilization of capacity and productivity that a decline in the volume o production may impede the general tendency of the growth of productivity and that for large drops in production, productivity may even decrease.

The changes in the utilization of capacity can — as opposed to the other significant factors affecting the productivity of labour — be fairly well determined quantitatively. In the case of industries with homogeneous products (such as aluminium metallurgy or some branches of the chemical industry), the utilization of capacity may be quite accurately evaluated numerically in natural quantities. For the whole of industry an approximation can be made using the highest level so far achieved (if necessary, adding the increase in capacity attained by new investments) in value, in the number of jobs that can be filled and possibly in the number of productive jobs available. (N. B. the latter figure is not given in contemporary industrial statistics.)

The exact relation between the utilization of capacity and productivity cannot, of course, be numerically established. An increase in the utilization of capacity generally involves enhanced productivity, because the proportion of those not directly engaged in production is relatively smaller.

Increases in the utilization of capacity thus continue to act favourably on the productivity of labour until they cause a degree of overloading, that endangers the safety and continuity of production. This overloading may be of an expressly technical nature, as in cases where productive equipment is overburdened so that it is damaged or sufficient time is not provided for maintenance, thus causing unexpected fall-outs, but it may also be of an economic nature. This occurs when disproportionate development takes place in the various sectors of industry and a shortage of materials or of power results, again leading to a fall-out and a decrease in productivity.

c) All classical and modern, marxist and bourgeois authors agree that the *skill* of those engaged in production *(the quality of the labour power)* is one of the most important factors of the level and development of productivity. Unfortunately, a thorough study of the relations between the development

of skill and of productivity is greatly hampered and, in fact rendered more or less impossible, by the fact that the quality of labour power can hardly be measured statistically, or its changes established (or even theoretically defined).

Figures that can be statistically established are generally not in close and direct connection with skill. The distribution of labour power among the three main categories (skilled, semi-skilled and unskilled) can be measured. These categories are, however, not unequivocal, they are subject to change with time, and have different meanings in the various trades. The numbers of technical specialists, or rather their proportion, and within this category, the numbers of those with engineering degrees or technician's diplomas, show somewhat more. Other aspects of the quality of labour power are shown by the distribution of age groups and the stability of labour force, *i. e.* the number of years spent at a given plant. However, all that can be said of the connection between these features and productivity, is that increases in experience, skill, etc., generally tend to enhance productivity. (Productivity does not, however, increase with increases in the proportion of skilled workers if, for instance, they are set to jobs that could just as well be done by semi-skilled workers.)

d) The main factors of changes in productivity that have so far been considered: the technical level, the utilization of capacity and the skill of the labour power may, with greater or less exactitude, be numerically evaluted and, in theory, their effect on changes in productivity could, on the basis of suitable investigations, be quantitatively established. The position is much more difficult with respect to the next, very important factor of changes in productivity, which will be dealt with more briefly. *Welfare and social factors* exercise an extremely important influence on labour productivity, especially during periods of rapid social changes. The rapid increase of labour productivity in Hungarian industry, for instance, between 1947—1950 and especially in 1949—1950 may undoubtedly be attributed, in part, to the tremendous political and social changes that took place in the life of the country. During this period the factories practically all became part of State Industry as a result of which the workers' attitude to their work underwent a fundamental change. There is also no doubt that increases in the standard of living promote increases in labour productivity, while a decrease in standards of living, especially if it is not transitional, considerably hampers this growth.

Of course, changes of a revolutionary character, such as the socialist reorganizations of industry, are of relatively short duration, after which a level of labour productivity and a rate of increase in productivity are established, which already reflect the effects of these factors. Therefore, their effects may then be taken into account in planning, in accordance with what are now already past points of departure.

e) Among the important factors shaping the level of labour productivity, are the *factors of nature*, such as the climate, raw material deposits, the location of centres of production and consumption, etc. As these factors of nature are constant, or at least change slowly, they have only a small effect on the change of productivity for the whole of industry. Their effect is mainly felt in the exploiting industries, such as mining, and there too, only in so far as the conditions for exploitation change, if certain deposits are exhausted and work takes place under increasingly adverse conditions, or if new deposits, providing more favourable conditions for exploitation, are discovered. The quantitative effects of these factors may be more or less accurately established and determined ahead. Their effect on the change in productivity of the whole of industry will generally — at least as far as the direct effect is concerned — not be great.

*

It may therefore be stated that changes in labour productivity may be planned according to the factors affecting productivity only for one branch of industry at a time — and that mainly in the case of industries with homogeneous, unified production profiles, product structures and production methods — but not comprehensively, for the whole of industry. The main reason is that the most important factors, the changes in the technical level and in the quality of labour power, cannot even be evaluated numerically. All long-range planning, therefore, whether explicitly or implicitly, contains some elements of extrapolation, *i. e.* it starts out from the increase in productivity over the previous period. In my opinion such methods of planning are not incorrect, provided of course, that the comprehensive figures obtained are only orders of magnitude, points of departure for the actual work of planning, and that an attempt is made as far as possible, in additional calculations based on the factors of changes in productivity to approximate the desired figures and, if necessary, to correct the global estimate made.

6. Another method which may be of help in planning labour productivity and that has not yet been mentioned in this paper, is *the international comparison of productivity*. Some authors, for instance the French economist, Jean Foutastié, who has written a great deal on labour productivity, says that as result of technical development the less developed countries eventually attain the labour productivity of the more developed countries and that this makes it possible to prepare long-range forecasts.

A statistical investigation of the international comparison of productivity does not bear out this optimistic view. The rate of growth of labour productivity greatly varies for the different countries and branches of industry. The ratios of the levels of productivity for various branches of industry are also very different in the various countries. The differences in productive

structure (and in price levels) make the comparisons themselves very uncertain. Nevertheless, the international comparison and analysis of labour productivity will probably afford a very good opportunity for discovering the actual relations pertaining and establishing the connections between the various factors and the level of productivity. In particular the comparison of the level of productivity of a given branch of industry with those of other countries and comparisons of the planned rate of increase with the rates of growth attained abroad, can be valuable aids to planning.

As with all measurements of productivity, here too the problem arises that reliable comparisons of the levels of production can only be made in respect to more or less homogeneous branches of industry, where both production and the live and embodied labour used in production, can for the greater part be expressed in natural units, thus eliminating the disturbing effect of the differing price systems.

It is also obvious that in regard to international comparison, there are tremendous, hitherto completely unexploited opportunities for the socialist countries. The co-operation of these countries differs qualitatively from that of the capitalist countries, their statistics are fully comprehensible, the enterprises have no interest in keeping figures secret and the comparison of productivity can depend not only on the — always incomplete — official statistics, but can also have recourse to direct links.

7. The planning of productivity is, of course, a part of economic planning in general, or as far as the present paper is concerned of the long-range planning of industry in particular and may, in itself, be taken from the complex whole of planning, only receive one-sided discussion. In order to limit the scope of discussion only a brief reference is made to some of the problems of the complex entirety of long-range planning.

Economic planning always takes place with a view to attaining certain set aims and on the basis of complex considerations to economic policy. The planning of productivity is subordinated to these aims. Basic economic considerations may relate to such problems as the proportion of the national income that may be devoted to investments, their distribution between the sectors of the people's economy and the various branches within industry, how much of the part ear-marked for industry should be devoted to modernization, to the expansion of existing equipment and to the creation of new capacity, all the time paying attention to the necessary level of employment set out in the balance of labour power and the supply of labour power to the various sectors. Other subjects considered include the development of domestic demand and of export requirements, export obligations, etc.

Although the growth of labour productivity is of fundamental importance for the development of the people's economy, it does not generally, within the system of long-range planning, figure as one of the main targets

of economic policy or of the plan (except for the development of the national income per head, which may, over the whole of the people's economy, also be considered as an index of productivity). The basic aims in preparing the plan are to achieve the correspondence of national income, accumulation, the standard of living, the balance of foreign trade and production by the various branches of industry, to bring about desirable proportions in the people's economy, etc. For the whole of industry and for its various branches the plans for labour productivity may be used as checks and are very important aids to planning. They make it possible to establish correspondence between the various balances and at the same time check the plan for correct economic development.

8. Scientifically founded and tested methods for the really accurate planning of the development of labour productivity are at present not available. The practice of planning is, however, fortunately better than its theoretical foundation and the planning bodies, on the basis of changes in the various factors affecting productivity, of previous development and of other practical information, nevertheless, plan increases in labour productivity to good approximate values. The question arises, whether it is necessary to aim at greater accuracy in planning? In my opinion, the answer must be in the affirmative. Examine, for instance, the development of the most comprehensive index of productivity, the net production per head (or per hour) in industry (which corresponds to the development of the part of the national income due to industry). If the level of productivity is lower than that planned then, provided the planned level of employment exists, this results in less national income, so that there will be insufficient reserves for either the standard of living to be raised or investments to be carried out. The deficit cannot, moreover, always be compensated by increasing employment. The economic plans of a socialist country naturally provide, in general, for the full employment of everyone who is able to work, so that there are usually no labour reserves available in excess of the plans. Even if there were, it is doubtful whether they would possess the necessary skill, or that there would be reserves of productive capacity permitting the employment of more labour power. If the net production per head for the whole of industry is lower than planned this, of course, also means that both the gross and the net productivities of certain branches of industry are smaller than planned. This, in its turn, again leads to a disturbance of the planned equilibrium of the people's economy in certain sectors.

These arguments may be answered by saying that labour productivity ought then to be planned with a reserve margin. It is, in fact, advisable to calculate with certain allowances. These reserves may, however, not be too large or else the plans would lose their incentive character and development would be slower than otherwise possible, moreover the planning of excessive

reserves may also upset the planned equilibrium. If, as a result of the reserve margin productivity in a given branch were to be a great deal higher than planned, this might result in the branch becoming unable to provide full employment for its workers because, for instance, it might be impossible to secure the necessary supply of materials. Naturally, during the course of the execution of the plans and the annual correction of long-range plans, numerous measures may be taken and are taken by the bodies concerned in securing the planned, proportionate development of the people's economy and to prevent the equilibrium being upset. However, even though the equilibrium is preserved, it may still be disadvantageous if, as a result of incorrect planning of productivity, proportions differing from those planned come to be developed in the people's economy. Plans for economic development, and in particular those for investments, set out from certain planned proportions for the whole of the people's economy and seek the most economic solutions corresponding to these proportions. If the proportions, in practice, develop differently, the planned investments may be less economical.

9. Improvements in the planning of labour productivity may only be achieved by means of improvements in the whole of planning. There are, of course, numerous tasks that are specifically connected with the measuring and planning of productivity. Reference has already been made in this paper to the fact that the international comparison of labour productivity would be of great service to planning. The Conference has also discussed the so-called direct measurement of productivity. If it were suitably developed, this might be a great help in analysing the various factors affecting changes in productivity, and thus in planning, based on these factors. Without aiming to include all, some further important tasks might also be mentioned. In recent years methods have been worked out to calculate the economy of investments and such methods are also applied in practice. These methods mainly examine the reimbursement times of investments. It would be correct to supplement these calculations with methods enabling the effect of investments on the labour power balance in general, and on labour productivity in particular, to be determined. Both in connection with planning investments and also for other reasons the planning of technical development and of the technical level ought to be better worked out, and within this the effects of changes in skill on productivity ought especially to be established. One of the obstacles to the planning both of labour productivity and of the whole of the volume of production is that we are not able to plan changes in the structure of production sufficiently accurately and sufficiently far ahead. Finally, I consider that it is necessary more precisely to measure and analyse the factors of changes in labour productivity — even if only by approximate methods — in order to be able, within a general rise in the level of planning, to perfect methods of planning productivity.

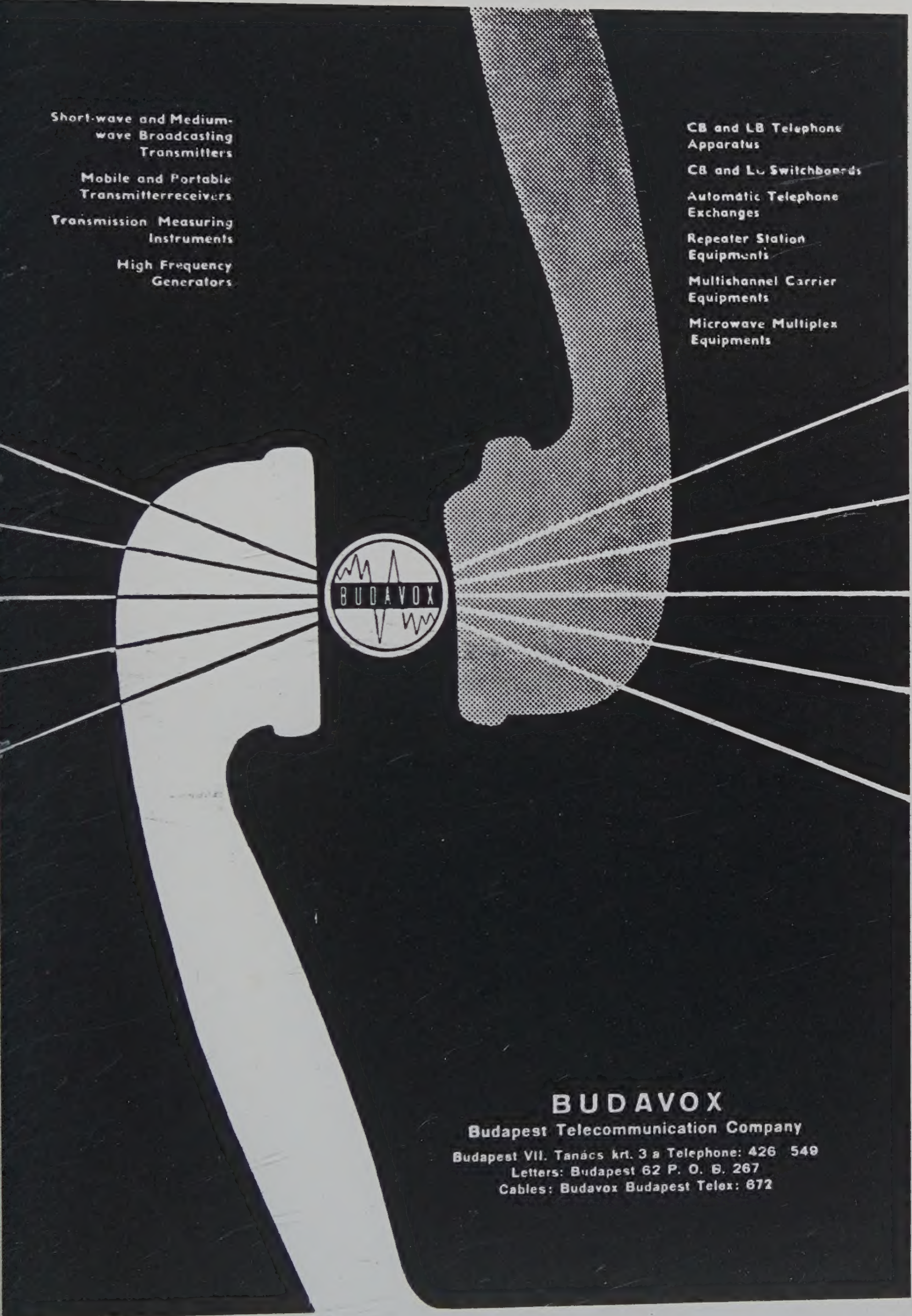
Summary

Economic literature holds that the planning of productivity may take place by some extrapolation of development over the previous period or by considering the factors influencing the level of productivity. Both methods, however, are fairly limited and do not at present, make accurate long-range planning possible. The plan of labour productivity first of all secures correspondence between the various balances in the system of plans for the people's economy (*e. g.* the correspondence between production and labour-power plans), moreover in long-range planning it may be one of the points of departure for the plan. Planning is facilitated by the fact that it is not necessary, for instance on the basis of the factors, to plan the absolute level of productivity, but only its change over the period concerned. The initial data for planning, which need to be well known, are the actual figures for the base period and the trend of development of productivity for a number of years retrospectively. In the case of planning based on the factors, the main factors are the technical level, changes in the utilization of capacity, the skill of the labour employed and factors of nature — besides welfare and social factors. The development of international comparisons of productivity would help to improve planning. The planning of productivity is at present not particularly well-founded scientifically, though in practice it is done better than the scientific foundations would warrant. It is, however, necessary to develop the method of planning because the optimal growth of the economy can only be planned if the development of productivity is closely approximated in the plan.

G. Cukor, Budapest V. Nádor u. 7. Hungary.

A kiadásért felel az Akadémiai Kiadó igazgatója
Műszaki szerkesztő: Farkas Sándor
A kézirat nyomdába érkezett: 1959. XII. 29. — Terjedelem: 4,75 (A/5) ív, 31 ábra

1960.50576 — Akadémiai Nyomda, Budapest, — Felelős vezető: Bernát György


Short-wave and Medium-wave Broadcasting Transmitters
Mobile and Portable Transmitterreceivers
Transmission Measuring Instruments
High Frequency Generators
CB and LB Telephone Apparatus
CB and LB Switchboards
Automatic Telephone Exchanges
Repeater Station Equipments
Multichannel Carrier Equipments
Microwave Multiplex Equipments
BUDAVOX
BUDAVOX
Budapest Telecommunication Company
Budapest VII. Tanács krt. 3 a Telephone: 426 549
Letters: Budapest 62 P. O. B. 267
Cables: Budavox Budapest Telex: 672

A Budapesti Műszaki Egyetem Periodica Polytechnica címen idegen nyelvű tudományos folyóiratot indított. A folyóirat három sorozatban — vegyészeti, villamossági, valamint gépész- és általános mérnöki sorozatban — jelenik meg, évente négyszer, sorozatonként egy-egy kötetben. Az egyes kötetek terjedelme 14—18 ív.

A Periodica Polytechnicában megjelenő tanulmányok szerzői az Egyetem tanári karából és tudományos dolgozóiból kerülnek ki. Főszerkesztő Dr. Csűrös Zoltán egyetemi tanár, akadémikus.

A folyóirat előfizetési ára sorozatonként és kötetenként 60,— Ft. Megrendelhető az Akadémiai Kiadónál (Budapest 62, Postafiók 440. NB. egyszámlaszám : 05-915-111-46), a külföld számára pedig a Kultúra Könyv és Hírlap Külkereskedelmi Vállalatnál (Bp. 62, Postafiók 149. NB. egyszámlaszám : 43-790-057-181), illetve a vállalat külföldi képviseleteinél és bizományosainál.

INDEX